BIOLOGY OF YOUNG LAKE TROUT (*Salvelinus namaycush*) IN LAKE MICHIGAN

By JOHN VAN OOSTEN
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Fishery Research Biologists

RESEARCH REPORT 42

Fish and Wildlife Service, John L. Farley, *Director*

United States Department of the Interior, Fred A. Seaton, *Secretary*

UNITED STATES GOVERNMENT PRINTING OFFICE • WASHINGTON • 1956

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Washington 25, D. C. • Price 40 cents

ABSTRACT

Experimental fishing with gill nets of 5 mesh sizes (2⅜ to 3 inches) in Lake Michigan in 1930–32 yielded more than 16,000 young lake trout. Data are presented here on age, growth, length-weight relationship, abundance, geographical and bathymetric distribution, and other details of their biology.

Four-year-old fish predominated in the collections. Time of resumption of seasonal growth and length of the growing season varied widely among individuals, and in different calendar years, age groups, and localities. Average annual increments in length varied from 3.4 to 4.6 inches in the first 3 years of life but were less during later years.

In lower Lake Michigan the average total length and weight of lake trout caught ranged progressively from 12.4 inches and 8.8 ounces in the 2⅜-inch mesh to 15.2 inches and 17.8 ounces in the 3-inch mesh. Average numbers of lake trout caught per net were nearly identical in the 2½-, 2⅝-, and 2¾-inch meshes, but were somewhat smaller in the 2⅜- and 3-inch meshes (a relationship explained in part by the predominance of the IV-group among young trout in the lake). The average total weight of trout caught per net increased progressively with each increase in mesh size.

Young lake trout were widely distributed in Lake Michigan and were taken at nearly all stations and at all depths fished. They were most abundant along the east shore of the lake, less plentiful in the northern region, and least numerous along the west shore. Highest concentrations of trout were at depths of 40–49 fathoms in the lower lake and at 30–39 fathoms in the northern region. Appreciable seasonal shifts in bathymetric distribution were not observed.

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BIOLOGY OF YOUNG LAKE TROUT (*Salvelinus namaycush*) IN LAKE MICHIGAN

In 1930–32 the former U. S. Bureau of Fisheries (now a part of the U. S. Fish and Wildlife Service) conducted an extensive investigation of the gill-net fishing for chubs (*Leucichthys* spp.) of Lake Michigan in cooperation with the States of Michigan and Wisconsin and the following four fish-net and twine companies, which furnished the original netting, maitre cord, and seaming twine: Linen Thread Co., Fish Net and Twine Co., R. J. Ederer Co., and Pauls Fish Net Co. The primary objectives of this investigation were to determine (1) the extent of the destructiveness of the small-mesh chub gill nets to immature lake trout (*Salvelinus namaycush*) and (2) the possibility of eliminating or reducing significantly this destruction by changing the size of the mesh of these nets and by restricting their use to certain depths of water or certain areas. In addition much information was also obtained on the chubs (Van Oosten 1933; Jobes, 1943, 1949a, b; Deason and Hile, 1947; Hile and Deason, 1947); on the food of the lake trout and burbot (Van Oosten and Deason, 1938); on the bottom fauna (Eggleton, 1936, 1937); on the phytoplankton (Ahlstrom 1936); on the surface currents (Deason 1932b); and on the distribution of the Cottidae (Deason 1939).

At the time of the investigation, three different sizes of mesh (2½, 2⅝, and 2¾ inches), stretched measure as manufactured, were employed by the chub fishermen of the four States that border on Lake Michigan. There was no agreement concerning which mesh was the least destructive to lake trout, and because no scientific data were available the State officials and legislatures were unable to take a definite stand on the controversial question. Each State was inclined to support the dominant views of its own fishermen. Neither did the several manufacturers of fish nets have any data on the subject. Their interest in the question was of course primarily one of finance. If one mesh size could be prescribed for all chub gill nets, these companies would then not be forced to stock large supplies of nets and netting with meshes of different sizes.

Since the investigation of 1930–32, some of the States have reduced the size of the prescribed mesh for taking chubs to 2⅜ and 2½ inches as used (measured with flexible rule) so that at the present time there is greater uniformity and less controversy. Certain other changes were also made in the laws, which

stopped the practice of shipping small lake trout to market. This change removed to a great extent the incentive to fish for young trout. Despite the altered situation, the early data on lake trout are still of great importance. We have little published information on the biology of the lake trout of the Great Lakes, and with the widespread appearance of the sea lamprey (*Petromyzon marinus*) in recent years in these lakes the trout have become so seriously reduced in numbers that it is now impossible to collect suitable data in some of these waters. The early data also provide us with a yardstick to measure the degree of reduction in abundance of the young lake trout in Lake Michigan. They also enable us to determine whether the increased numbers and spread of the sea lamprey affected the distribution, growth, and general welfare of these young trout.

We are indebted to many persons, too numerous to mention by name, whose splendid cooperation greatly facilitated the investigation. We are especially grateful to Howard K. Balch, through whose personal efforts was obtained the fine cooperation of the four fish-net and twine companies, and the late William H. Loutit, Chairman of the Michigan Conservation Commission, and the late Matt Patterson, Deputy Director of the Wisconsin Department of Conservation, at the time of the investigation, who were primarily responsible for obtaining the funds provided by the States of Michigan and Wisconsin. Fred A. Westerman and Captain Charles J. Allers, of the Michigan Department of Conservation also devoted considerable time and effort to make the investigation a success.

MATERIALS AND METHODS

Deason (1932a) gave a detailed account of the procedures employed in the field, but since his paper is generally inaccessible some of this information will be repeated here. The now dismantled 102-foot vessel *Fulmar* (fig. 1) was completely remodeled to serve the needs of the experimental-fishing and hydrographic program. Three reels for drying gill nets were constructed on the stern of the vessel so that fishing operations could be carried on wholly independent of the shore. Five sizes of mesh (2⅜, 2½, 2⅝, 2¾, and 3 inches, stretched measure as manufactured) were used in the experimental linen gill nets, each of which was 510 feet long (about 60 leads) and 5 feet deep, the standard size used by the commercial fishermen at that time. The nets were made of 50/2-cord, single-selvage twine and were strung ½ mesh more than on the one-half basis, 6 meshes to a tie (e. g. six 3-inch meshes were hung to a 10½-inch tie instead of a 9-inch tie). Each net was fitted with ⅝-inch pipe leads 3 inches long and No. 1 aluminum floats. To ensure uniformity the twine was furnished and the nets were made up by one company.

All five sizes of mesh were employed in 1930 (June–November) and 1931 (April–November) when

Figure 1.—The U. S. Maritime Service vessel *Fulmar*, used in experimental gill-net fishing on Lake Michigan, 1930–32.

nearly all fishing was confined to the area south of an imaginary line extending from Frankfort, Mich., to Algoma, Wis. (see map, fig. 2). In late September and early October of 1930 some fishing was done in Green Bay when only the three smallest sizes of mesh were employed. In 1932 (April–September) all fishing was conducted north of the above-defined line and in Green Bay (April–May), and only the three intermediate sizes of mesh ($2\frac{1}{2}$, $2\frac{5}{8}$, $2\frac{3}{4}$) were used, except in Green Bay where the $2\frac{3}{8}$-inch mesh was added to the series part of the time. All nets were set on the bottom.

When operating south of the above-described line, the usual procedure was to fish simultaneously out of six ports, three on the west shore and three on the east shore (see map, fig. 2, for location of stations). During the late fall, when crossing the lake became hazardous, operations were restricted to the west shore, where harbors remained free of ice longer than on the east shore. At least two gangs, each comprising nets with the same series of mesh sizes, were fished out of each port where possible—a shallow-water gang set in water up to about 45 fathoms deep and a deep-water gang set in depths usually greater than 50 fathoms. A standard gang consisted of one

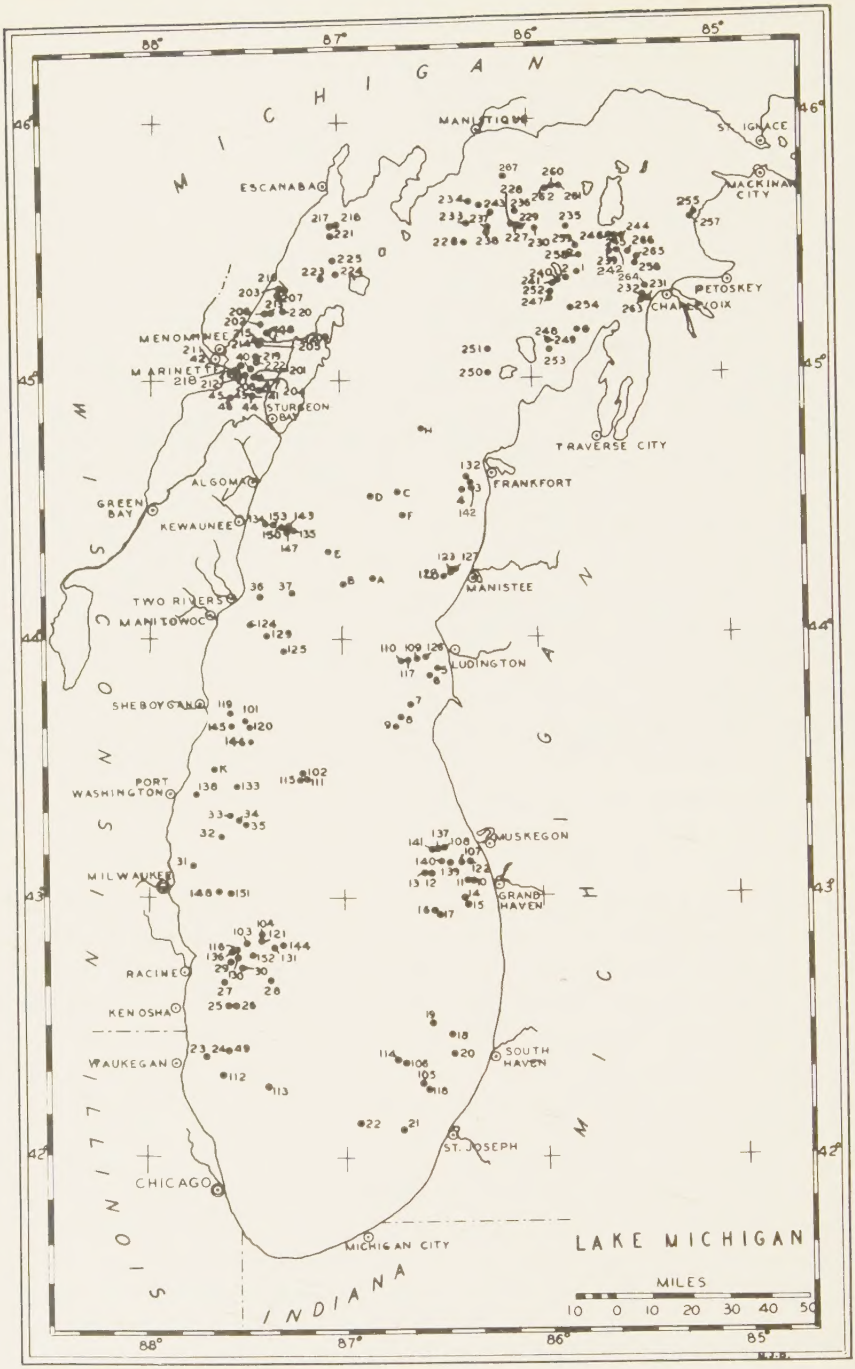

Figure 2.—Map of Lake Michigan, showing stations where experimental gill nets were set for the collection of lake trout and chubs, 1930–32. Station numbers 1–48 were occupied in 1930, 101–153 in 1931, and 201–267 in 1932. Only limnological data were collected at stations A–K.

net of each of the sizes of mesh employed in the section of the lake under investigation. The number of nets per gang varied from three in northern Lake Michigan to five in the more southern part of the lake. The number of gangs per lift varied in accordance with the number of nets used or the abundance of fish taken.

Data were recorded on the total bulk weights and numbers of all lake trout, chubs, and other fish taken by the nets of each size mesh. The chubs were sorted by species whenever time permitted, and biological data and scales were collected. Biological data were also recorded for the lake trout and burbot (*Lota lota*); stomachs but no scales were taken from these species. Fortunately, a large series of trout was preserved for racial studies, and it is from these preserved fish that the scales used in this study were collected. All measurements and weights of these fish were made in the field before preservation. Sex was not determined for the preserved trout, nearly all of which were immature.

At each net station, as time and weather permitted, water temperatures were recorded with reversing thermometers, and bottom and plankton samples were collected in the usual manner with a Petersen dredge and silk cone nets of fine mesh. A series of drift bottles was released to study surface currents.

Ages and growth were determined for 811 lake trout taken at various ports in 1930, 1931, and 1932 (table 1). Seventeen of these fish were taken in specially treated nets with meshes of 2¾ inches. They were not used in all tables employing ages—for example, in the sections on age composition and abundance of fish. Lengths were computed from both the radius and the diameter of the scales of 582 trout. In addition, scales of 217 presumably fin-clipped lake trout of known age, captured out of Manistique, Mich., in 1947–50, were carefully studied in order to learn the identifying characteristics of an annulus and to determine the time of annulus-formation. Likewise, scales from a few small lake trout (under 8 inches) taken from Michigan lakes and the

Table 1.—Location and date of capture of 811 lake trout for which age determinations and growth calculations were made

Port	Course	Distance (miles)	Station No.	Date	Number of fish
Kenosha, Wis	E	11.4	25	Nov. 10, 1930	23
Racine, Wis	SExE3/4E	12.0	27	Aug. 8, 1930	17
Racine, Wis	ESE3/4E	21.8	28	Aug. 8, 1930	
Racine, Wis	ExN1/2N	22.5	144	Oct. 21, 1931	47
Sheboygan, Wis	SE1/2S	7.5	145	Nov. 18, 1931	64
Sheboygan, Wis	SE1/2S	12.7	146	Nov. 18, 1931	
Kewaunee, Wis	ExS1/4S	5.3	153	Nov. 19, 1931	81
Green Island, Wis	near Island		41	Sept. 23, 1930	13
Menominee, Mich	SSE7/16E	7.0	211	May 10, 1932	206
Escanaba, Mich	S1/8W	14.0	221	May 26, 1932	20
Manistique, Mich	SSE	26.5	227	June 15, 1932	61
Manistique, Mich	SE1/8E	23.8	261	Aug. 31–Sept. 1, 1932	52
Manistique, Mich	SSE5/16E	14.8	267	Aug. 31–Sept. 1, 1932	
Charlevoix, Mich	W5/16N	30.5	241	July 30, 1932	150
Charlevoix, Mich	W1/8S	35.0	252	Aug. 13, 1932	12
Leland, Mich	NWxW3/4W	11.2	253	Aug. 16, 1932	19
Ludington, Mich	SW7/8S	7.5	5	Aug. 13, 1930	46
Ludington, Mich	SW7/8S	25.3	9	Aug. 13, 1930	

Great Lakes were examined, the average lengths of recaptured fin-clipped lake trout from the Great Lakes were computed by age groups, and records of growth of Great Lakes lake trout reared in hatcheries were studied as further checks on the accuracy of our scale readings.

The numbers of specimens used for certain other phases of the investigation were as follows: Length frequencies, 14,414; length-weight relationship and coefficient of condition, 11,228; standard length-total length relationship, 11,571; sex ratio, 13,529. Information on bathymetric and geographical distribution and abundance was obtained from fish taken in 3,717 standard gill nets.

All length measurements and weights were obtained from fresh specimens in the field. All lengths, recorded to the nearest millimeter, were procured by holding a steel tape as nearly parallel as possible to the long axis of the body. Total lengths represent measurements from the tip of the snout to the end of the tail fully extended; standard lengths, from the tip to the base of the caudal peduncle. All weights of the individual fish were recorded to the nearest quarter of an ounce. Scales were mounted in glycerin-gelatin on glass slides as described by Van Oosten (1929) and were examined and measured by means of the microprojection machine described by Van Oosten, Deason, and Jobes (1934). Ages are expressed in roman numerals that correspond to the number of annuli found on the scales or to the number of winters through which a fish has passed. All calculated lengths employed for the study of growth were obtained by direct-proportion computation based on the diameter measurements of the scales.

TECHNIQUES OF AGE AND GROWTH DETERMINATIONS FROM SCALES

Determining the ages of lake trout from the Great Lakes has been a difficult and tedious job. The portion of the scale laid down in the first year of life usually gave the most trouble. This central zone was at times very indistinct and small and was often represented by only a few crowded and broken circuli (see figs. 5 and 10). Because calculations of length based on this "central check" were unexpectedly small, it was at first believed that this check did not represent the first year's growth. However, since it persisted throughout all collections and the vast majority of first-year computations based on clear-cut annuli (see fig. 9) were likewise small, it was finally concluded that all of the "central checks," irrespective of size, were true annuli. On this basis, the data became consistent throughout a collection.

It was also observed that a break and the approximation of only a few circuli (sometimes only two) may represent an annulus. Further, the boundary of an annulus was often defined by a whorled circulus—not by a single, continuous circulus—which made it difficult to determine exactly the limits

(used for scale measurements) of the growth zone in the anterior and posterior fields. Sometimes, for the later years of life, an annulus could be recognized largely by an area of indefinite, broken circuli in the anterior field. Considerable variation existed in the distinctness of annuli on scales of different sizes and shapes taken from the same fish. Unless extreme care is exercised, a lake-trout annulus is easily overlooked. (See figs. 3–14 for variations in distinctness of annuli of fish of different ages. Magnifications of the scales are not the same.)

The technique of determining ages of lake trout requires: (1) Information not only on the date of collection but also on the size of the fish at capture; (2) the mounting of about a dozen scales of different sizes and shapes; and (3) the calculation of length for each year of life of each individual fish of uncertain age in order to check the reasonableness of the interpretation of an annulus with respect to its location on the scale. Size of fish alone cannot be utilized as a check because of the great variability in the length of trout of the same age.

Before reaching a decision on the technique that was finally adopted, many scales were read two (298 fish) and three (171 fish) times, 168 were remeasured, and new computations of length were made. Weeks intervened between the repeated readings and measurements. In addition, use was made of fin-clipped, hatchery-reared, and small wild lake trout as stated on page 5. These fish of known age or small size indicated growth in total length at the end of each year of life, beginning with the first, of the following magnitude: 4, 7 to 8, 11½, 14, and 16 inches. These values gave us confidence in our final interpretation of the scales.

In the past, standard lengths in millimeters of fish at capture were generally employed for computations of growth based on scales since the scale theory assumes that only the scaled part of the fish's body is related to the growth of scales. The modern tendency has been to employ total lengths stated in inches.

The lake trout collected in 1930–32 and used for a study of growth were measured in two ways: standard length and total length (both in millimeters). It is therefore possible to make some comparison between calculated growths based on both systems of measurement. Two age groups were employed for this purpose: III and IV from Charlevoix, taken July 30, 1932 (table 2). All lengths at capture, originally given in millimeters, were first converted to inches, and these figures were then employed in computing lengths, both standard and total, from the scale-diameter measurements. The computed average standard lengths were then converted to total lengths by multiplying them by the factors 1.187 and 1.189 for age groups III and IV, respectively. These converted values were then compared with the total lengths computed directly from the scale measure-

Figure 3.—Lake Michigan lake trout, age group II, 1 annulus, total length 7.2 inches. Taken May 11, 1932. First-year calculated length - 3.1 inches. Growth not resumed in 1932.

Figure 4.—Lake Michigan lake trout, age group II, 2 annuli, total length 7.9 inches. Taken May 11, 1932. First-year calculated length = 3.4 inches. Growth resumed in 1932.

Figure 5.—Lake Michigan lake trout, age group III, 2 annuli, total length 11.1 inches. Taken May 10, 1932. Small first-year calculated length (2.5 inches). Growth not resumed in 1932.

Figure 6.—Lake Michigan lake trout, age group III, 3 annuli, total length 11.6 inches. Taken May 10, 1932. Third annulus at edge.

Figure 7.—Lake Michigan lake trout, age group III, 3 annuli, total length 12.9 inches. Taken May 10, 1932. Large first-year calculated length (4.8 inches). Growth resumed in 1932.

Figure 8.—Lake Michigan lake trout, age group III or IV, 3 annuli, total length 14.0 inches. Taken July 30, 1932. Large marginal scale growth. Either growth had not resumed in 1932 (IV) or it was virtually completed (III). Last year's calculated increment = 3.6 inches.

Figure 9.—Lake Michigan lake trout, age group IV, 4 annuli, total length 12.3 inches. Taken October 21, 1931. Small first-year calculated length (2.2 inches). Small marginal growth. Last year's calculated increment = 0.6 inch.

Figure 10.—Lake Michigan lake trout, age group V, 5 annuli, total length 14.4 inches. Taken July 30, 1932. Small first-year calculated length (2.4 inches). Good marginal growth. Last year's calculated increment=1.9 inches.

Figure 11.—Lake Michigan lake trout, age group VI, 6 annuli, total length 17.7 inches. Taken June 15, 1932. Last annulus near margin.

Figure 12.—Lake Michigan lake trout, age group VII, 6 annuli, total length 19.0 inches. Taken June 15, 1932. Growth not resumed in 1932. Last year's calculated increment = 2.1 inches.

Figure 13.—Lake Michigan lake trout, age group VIII, 8 annuli, total length 17.2 inches. Taken August 8, 1930. Growth resumed in 1930. Last year's calculated increment—1.2 inches.

Figure 14.—Lake Michigan lake trout, age group X, 9 annuli, total length 27.0 inches. Taken June 15, 1932. Growth not resumed in 1932. Last year's calculated increment = 2.0 inches.

ments. The data of table 2 show that the converted total lengths were almost identical in every year with the computed averages. It is valid, therefore, to employ total lengths in computing the growth histories of lake trout from their scales (see also Van Oosten, 1953).

In the lake trout scales it was possible to measure both the radius and the diameter of each growth zone. Inasmuch as lengths computed from the radial measurements of scales have been found to be almost invariably too low in all species of fish and the use of diameters in the lake herring has been found (Van Oosten 1929) to give higher and more accurate values than the use of radii, it was deemed advisable to compute lengths of lake trout from both types of scale measurements. It was found, when the number of fish was sufficiently large, that scale diameters always gave higher calculated lengths than radial measurements. This result persisted for the fish of all localities. The differences between the two sets of computations generally varied little with the samples. Hence the combined data of all collections represent well the true situation everywhere (table 3).

The figures of this table show that the greatest difference (0.89 inch) occurred in the second year of life and that this value decreased progressively in the third, first, fourth, and fifth year (0.46). Numbers of specimens employed for later years were small. The percentage difference, however, decreased progressively from the first (18.0) through

Table 2.—Comparison of total lengths obtained by conversion of calculated standard lengths, employing factors 1.187 and 1.189 for age groups III and IV, respectively, with total lengths obtained by computations based directly on scale-diameter measurements

[All lake trout were taken off Charlevoix, Mich., on July 30, 1932]

Age group and kind of length	Length at capture (inches)	Calculated length (inches) for year—			
		1	2	3	4
Group III (63 fish):					
Standard length	11.31	3.19	6.45	8.83	
Converted total length	13.43	3.79	7.66	10.48	
Total length	13.43	3.79	7.66	10.48	
Group IV (72 fish):					
Standard length	11.92	2.81	5.74	8.08	10.02
Converted total length	14.18	3.34	6.82	9.61	11.91
Total length	14.18	3.34	6.82	9.62	11.92

Table 3.—Summary, for all localities and all dates combined, of calculated total lengths based on the diameters and radii of scales of 582 lake trout, sexes combined, taken in 1930–32

Item	Weighted grand average of calculated total lengths (inches) for year—							
	1	2	3	4	5	6	7	8
Diameter	3.40	6.93	9.91	11.94	13.85	16.69	17.87	18.52
Radius	2.88	6.04	9.20	11.46	13.39	16.12	17.50	17.95
Difference	0.52	0.89	0.71	0.48	0.46	0.57	0.37	0.57
Percentage difference	18.0	14.7	7.7	4.2	3.4	3.5	2.1	3.2
Number of fish	582	582	575	376	109	23	7	2

the fifth year (3.4), and thereafter probably remained constant. All computations of length used in our discussions of growth have been based on diameter measurements.

It has been customary in the past to derive averages of computed growth from calculations made for individual fish. This method involves considerable mathematical manipulation. Theoretically, it should be possible to obtain the same information by averaging the scale-diameter measurements for each year of life and computing the lengths from them and the average length of the fish employed. This theory was tested for lake trout of age groups III, IV, and V taken, respectively, at Menominee and Charlevoix in 1932, at Ludington, Menominee, and Charlevoix in 1930 and 1932, and at Sheboygan, Manistique, and Charlevoix in 1931 and 1932 (table 4).

The data show that the discrepancies between the two series of computations were insignificantly small varying from 0.0 to 0.04 inch. The unweighted grand average differences never exceeded 0.01 inch in any year of life. It is clear, then, that it is not necessary to compute the growth for each individual lake trout in order to obtain averages for any particular age group. However, in this study of the 1930–32 fish, we have found it necessary to do so because of the difficulties encountered at the beginning in identifying the annuli on the scales. In any later studies of the lake trout, it will be necessary to compute growth for individual fish only when the validity of an annulus is in doubt. (For further discussion on this subject as related to other species, see Van Oosten 1953.)

Table 4.—Comparison of calculated total lengths based on averages of scale-diameter measurements and on computations from scales of each individual fish

Locality and date	Age group	Number of fish	Length (inches) at capture	Based on diameter—	Calculated total length (inches) for year—				
					1	2	3	4	5
Menominee, May 10, 1932	III	156	11.72	Average	3.46	7.63	11.38		
				Individual	3.48	7.63	11.35		
				Difference	−0.02	0.0	0.03		
Charlevoix, July 30, 1932	III	63	13.43	Average	3.78	7.66	10.48		
				Individual	3.79	7.66	10.48		
				Difference	−0.01	0.0	0.0		
Ludington, Aug. 13, 1930	IV	22	14.35	Average	3.89	6.94	9.88	12.35	
				Individual	3.87	6.93	9.87	12.37	
				Difference	0.02	0.01	0.01	−0.02	
Menominee, May 10, 1932	IV	44	12.59	Average	3.45	7.12	9.84	12.50	
				Individual	3.45	7.12	9.85	12.50	
				Difference	0.0	0.0	−0.01	0.0	
Charlevoix, July 30, 1932	IV	72	14.18	Average	3.33	6.80	9.61	11.93	
				Individual	3.34	6.82	9.62	11.92	
				Difference	−0.01	−0.02	−0.01	0.01	
Sheboygan, Nov. 18, 1931	V	20	15.38	Average	2.94	6.35	9.23	11.60	13.76
				Individual	2.95	6.34	9.23	11.60	13.77
				Difference	−0.01	0.01	0.0	0.0	−0.01
Manistique, June 15, 1932	V	20	14.59	Average	2.94	6.40	9.45	12.08	14.32
				Individual	2.93	6.38	9.44	12.08	14.32
				Difference	0.01	0.02	0.01	0.0	0.0
Charlevoix, July 30, 1932	V	14	15.85	Average	3.09	6.39	9.43	11.84	13.95
				Individual	3.11	6.40	9.47	11.88	13.97
				Difference	−0.02	−0.01	−0.04	−0.04	−0.02

ACCURACY OF AGE DETERMINATIONS AND THE GROWING SEASON

As stated on page 5, the scales of 217 lake trout, presumed to have been fin-clipped and recaptured, were studied in order to determine the characteristics of an annulus, the time of its formation, and the accuracy of our age and growth determinations from scales. All of these trout were taken out of Manistique, Mich., in 1947–50. Five of these fish could not be fully utilized because their exact ages were unknown. Of the remaining 212 trout, 42 were assigned ages as based on scales that disagreed with those based on missing or deformed fins. There was thus an apparent discrepancy of 20 percent.

The disagreements do not necessarily reflect unfavorably on the scale method. Some of the trout with missing or deformed fins were evidently not fin-clipped fish as, for example, the designated 1-year-old with the unreasonable length of 12.3 inches. As reported by Van Oosten (1950), the occurrence of deformed or missing fins in nature is not unusual although only a small percentage (about 0.14) of the wild trout examined showed such abnormalities. Other discrepancies were the results of trying to assign a definite age to difficult scales. As has always been true in scale analysis, a certain percentage of the scales cannot be read with positive assurance because of the presence of one or more ill-defined annuli or the occurrence of accessory marks or the preparation of poor mounts. Wholly unreadable scales are, of course, discarded.

The disagreements were most common in the older fish of age groups IV and V. Of the 42 discrepancies 34 (81 percent) differed by 1 year, and 8 (19 percent) by 2 years. Ten of these 42 age determinations were also assigned a questionable age, 7 of which would have been correct if they had been definitely chosen. The disagreement of 20 percent would then have been reduced to 16 percent. It should be stated that scale readings were made without any knowledge whatsoever of the ages assigned to the trout on the basis of missing or deformed fins.

Table 5 shows the percentage of fin-clipped lake trout that had resumed growth (annulus at edge or marginal growth on scales) at various periods of time, usually weekly intervals. Only those fish were employed whose ages based on scales agreed with those based on missing or deformed fins. Data for all 4 years (1947–50) were combined. The combined percentages show that only about one-fourth of the fish had resumed growth by the end of the first week in July. By the middle of the month about 50 percent and by August 4 some 80 percent had begun their new growth. It was not until the latter half of August that from 90 to 100 percent of the fish had resumed growth (100 percent after August 25). These results are rather unexpected as it has generally been found with few exceptions that the annuli on the scales of fish of any single population of our northern lakes

normally form within a week or two during the period of April–June. No correlation was found between the time of resumption of growth and the ages of the fin-clipped trout.

The extended period of time of annulus-formation (May–August) and the lateness of the final date of this period make age determinations of lake trout from the Great Lakes very difficult when their scales are collected during the summer months. We cannot always be certain that the marginal growth on such scales represents the new or old increment (see figs. 8, 10, 12). No difficulties in these respects should be encountered in fish taken early or late in the growing season.

Since a considerable number (table 1) of our 1930–32 lake trout employed for age determinations was collected during the critical period of annulus-formation, an attempt was made to learn also from the scale and growth increments of these fish the probable dates of growth resumption. Comparisons can then be made with the data obtained from the fin-clipped trout of presumably known ages.

The earliest collections of the year were made in May–June 1932 from the northern waters of the lake. Little difficulty was encountered in analyzing the scales of these trout and separating those that had and had not resumed growth (see figs. 3, 4, 5, 6, 7). In the half dozen specimens in question from Menominee, Mich., the final analysis was made by comparing their terminal (last) increments of growth and their total lengths with the standards shown and explained in table 6. Standards were first compiled for the upper and lower lake separately in the belief that they might be different. However, comparisons revealed that the discrepancies were insignificantly small. It is believed that one set of these standards covers very well the entire lake.

Table 5.—Number and percentage of fin-clipped lake trout taken in 1947–50 out of Manistique, Mich., that showed a resumption of growth at the periods of time indicated

[Only those fish were employed whose age determinations from scales agreed with the presumed known age] The asterisk indicates that no specimens were taken; zero shows that none of the fish taken had resumed growth.

Dates	Total number of fish	Growth resumed by—							
		Age group III		Age group IV		Age group V		All age groups	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
May 27–June 23	9	(*)	(*)	2	22	(*)	(*)	2	22
July 1–7	22	(*)	(*)	3	15	2	100	5	23
July 8–14	29	(*)	(*)	11	42	3	100	14	48
July 15–21	7	2	50	1	50	0	0	3	43
July 22–28	16	1	100	9	82	0	0	10	62
July 29–Aug. 4	21	1	100	16	80	(*)	(*)	17	81
Aug. 5–11	24	8	80	10	91	3	100	21	88
Aug. 12–18	24	1	100	18	100	3	60	22	92
Aug. 19–25	3	2	67	(*)	(*)	(*)	(*)	2	67
Aug. 26–Sept. 1	8	1	100	6	100	1	100	8	100
Sept. 2–Oct. 6	7	(*)	(*)	4	100	3	100	7	100
Total	170	16		80		15		111	
Number available	170	21		127		22		170	

Table 8.—Percentage of July 30 lake trout that resumed growth in 1932, determined from comparisons of individual increments and total lengths with standard measurements (table 6) based on assumption A (p. 25), and percentage of lake trout that had completed a full-year's growth in 1932, determined from same comparisons based on assumption B

[Figures in parentheses represent total number of fish in an age group]

Item	Age group III	Age group IV	Age group V	Age group VI	All groups
Percentage of lake trout resuming growth (A)	80 (5)	27 (81)	14 (58)	0 (6)	23 (150)
Percentage of lake trout completing growth (B)	94 (63)	69 (72)	43 (14)		77 [1] (150)

[1] 1 fish in group II had a full-year's growth.

further discussion see below). It is not valid, then, to make similar comparisons under assumptions (A) and (B) for the later dates inasmuch as it is certain that some of the fish, especially the younger individuals, had acquired a new full-year's terminal growth by August.

With respect to the third method of checking resumption of growth (p. 25), it may be pointed out that in the sample of May 10, 1932, our earliest in the year, there occurred a pronounced break between the terminal increments of those trout that had resumed growth in 1932 and those that had not resumed it. The standards of table 6 supported the separation of the two groups. However, no such delimiting gaps occurred in the terminal increments of the fish taken on May 26 and June 15, 1932, or on any later date in that year. Six pronounced breaks out of 13 possibilities were found in the 1930 and 1931 samples, but they involved only 7 fish with the higher increments out of 235 specimens. It appears, therefore, that the presence or absence of marked breaks in the series of terminal increments of growth may not be employed as a criterion to determine whether growth had or had not been resumed after early spring.

To confirm this conclusion we also examined the 1929–31 increments of growth of the 1930–32 trout. We discovered that major breaks occurred more frequently in the completed increments (10 times) than in the terminal growths (7 times) of the same fish.

There seems to be no method whereby we can positively determine whether an individual trout taken during the late spring and early summer had resumed growth. That renewal of growth may be delayed until very late in the season is evidenced by (1) the small terminal increments of growth of trout caught as late as October (0.6 inch, fig. 9), and (2) the failure of the mean terminal increments and total lengths of the age groups to increase progressively after July as the season advanced to November (table 9). (See also discussion on resumption of growth by the fin-clipped fish, p. 22.)

It is possible to obtain some idea of its completeness once the seasonal growth of an individual has started by comparing the computed terminal increment and total length with the standards of table 6, such

Table 9.—Averages of terminal increments of growth and total lengths of lake trout of several age groups taken on different dates in 1930–32

Locality and date	Terminal increments (inches)						Average total lengths (inches) [1]		
	Age group III		Age group IV		Age group V		Age group III	Age group IV	Age group V
	Number	Average	Number	Average	Number	Average			
Menominee, May 10, 1932	62	0.8	5	0.8	1	0.8			
Escanaba, May 26, 1932	1	1.2	3	1.1					
Manistique, June 15, 1932	3	1.5	6	1.1	5	1.1			
Charlevoix, July 30, 1932	63	3.0	72	2.3	14	1.9			
Charlevoix, Aug. 13, 1932	1	5.7	10	2.1	1	1.6	15.3	14.5	15.1
Leland, Aug. 16, 1932	6	2.6	12	2.4			13.9	15.1	
Manistique, Aug. 31–Sept. 1, 1932	12	2.8	28	2.2	9	1.8	13.3	15.0	16.4
Racine, Oct. 21, 1931	7	1.8	27	1.4	11	1.8	12.4	13.1	15.1
Sheboygan, Nov. 18, 1931	9	1.6	25	1.6	20	1.6	12.6	13.1	15.4
Kewaunee, Nov. 19, 1931	19	1.7	45	1.7	14	1.6	13.1	13.7	14.4
Racine, Aug. 8, 1930	6	1.9	3	1.5	5	2.2	11.9	13.9	16.3
Ludington, Aug. 13, 1930	12	1.9	22	2.0	9	1.5	12.5	14.4	15.1
Kenosha, Nov. 10, 1930	4	1.9	12	1.5	3	2.1	12.0	13.4	15.3

[1] The same numbers of fish were employed for the lengths as for the increments. Specimens collected before August in 1932 cannot be compared for total lengths with those caught later because different meshes were employed in taking them.

Table 10.—Percentage of lake trout that had completed a full-year's growth in the year of capture

[Determined from comparisons of individual growth increments and total lengths with the standards of table 6 and based on assumption B (see p. 25). Figures in parentheses represent total number of fish in an age group]

Locality and date	Age group—			
	III	IV	V	III–V
Charlevoix, July 30, 1932	94 (63)	69 (72)	43 (14)	77 (149)
Charlevoix, Aug. 13, 1932 Leland, Aug. 16, 1932 Ludington, Aug. 13, 1930 Manistique, Aug. 31–Sept. 1, 1932	74 (19)	70 (44)	20 (10)	64 (73)
Green Island, Sept. 23, 1930	75 (12)	57 (28)	56 (9)	61 (49)
Racine, Oct. 21, 1931	90 (10)	33 (3)		77 (13)
Sheboygan, Nov. 18, 1931	57 (7)	22 (27)	36 (11)	31 (45)
Kewaunee, Nov. 19, 1931 Kenosha, Nov. 10, 1930	78 (32)	45 (82)	40 (37)	51 (151)
Unweighted averages	76	53	39	

as has already been done for the specimens of July 30, 1932 (table 8). The results of such comparisons are shown in table 10 for the different collections taken after the spring of the year. From these data we may conclude (1) that during the period, July–November, the percentage of trout that had completed growth decreased with increased age in fish 3 to 5 years old, (2) that this percentage did not rise consistently with the advance of the season until after October, probably because of the inclusion in each later sample of individuals that had just begun to resume growth—the late starters, (3) that in general a greater percentage of individuals had completed their

growth earlier in the season in upper than in lower Lake Michigan although this differential may have been related to the different years, and (4) that the growing season may extend beyond the middle of November, at least in lower Lake Michigan. (Only 51 percent of these trout had completed their growth by the middle of this month.) Pronounced fluctuations in rate of completion of seasonal growth may be expected among the lake trout because of the wide spread in the time of resumption of growth, the variation in the growth rates of individual trout, and the differences in the environmental factors that affect growth.

AGE COMPOSITION

Table 11 shows the age composition of the samples of lake trout (sexes combined) taken in gill nets with different sizes of mesh. In order to learn whether it was valid to combine these data for each mesh for different localities, dates, years, and depths of water, tables were set up for each individual collection. After a careful examination of these different tables and of various combinations of the data, it was determined that the shallow-water collections from central Green Bay (Menominee and Green Island) should be considered separately (see p. 29) but that all other samples could be consolidated in this study.

In support of this consolidation it may be pointed out (1) that samples from the lake proper that constituted from 47 to 77 percent of their respective lifts gave the same results

Table 11.—Number and percentage of lake trout of each age group taken in gill nets with different sizes of mesh, 1930–32

[Sexes combined. Data from shallow-water and deep-water lifts combined]

Locality and mesh size of nets	In age group—																Total number of fish
	II		III		IV		V		VI		VII		VIII		X		
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
All localities exclusive of Menominee and Green Island:																	
2⅜ inches			15	37	21	51	4	10					1	2			41
2½ inches	3	2	32	25	69	54	18	14	3	2	2	2					127
2⅝ inches	1	1	42	30	66	48	21	15	9	6							139
2¾ inches	2	1	47	23	107	53	34	17	9	4	3	2			1	(1)	203
3 inches			4	6	22	34	30	46	4	6	4	6	1	2			65
All sizes	6	1	140	24	285	50	107	19	25	4	9	2	2	(1)	1	(1)	575
Menominee, May 10, 1932:																	
2⅜ inches			61	87	8	11	1	1									70
2½ inches			49	82	9	15	2	3									60
2⅝ inches			30	73	10	24	1	2									41
2¾ inches			16	46	17	49	2	6									35
All sizes			156	76	44	21	6	3									206

[1] Less than 0.5 percent.

with regard to dominance and trends in relative abundance of age groups as those that represented from 90 to 95 percent of the catch and included only comparable materials, and (2) that the average age composition (percentages) of the trout from lower Lake Michigan corresponded almost exactly with that of the fish from the upper lake.

Age group IV dominated the consolidated samples of all nets except those with meshes of 3 inches in length where the V-group ranked first and the IV-group second. In all other nets age-group III ranked second followed by the V-group. Age groups III and IV contributed the bulk (76 to 88 percent; average 78) of the catch in all nets except those with meshes of 3 inches where groups IV and V furnished 80 percent. Age groups III, IV, and V contributed from 86 to 98 percent (average 92) to the samples whereas groups II, VI, and older fish supplied a combined total of 2 to 14 percent with an average of only 8 percent. In explanation of these small percentages, we may state that the trout under 3 years of age were no doubt the largest individuals of their age group (see table 20), and those over 6 years of age were more or less accidental captures. In each group of nets the percentage of occurrence rose with an increase in the age of trout to the fourth year and then decreased through the sixth year, except in the nets with meshes of 3 inches where the decline did not take place until this latter year.

There were no definite, marked trends in the percentages of occurrence of an age group with the increase in the size of mesh, although in age group V there was a slight tendency for them to rise, culminating with a sharp increase in the 3-inch-mesh nets and a corresponding marked decline in age groups III and IV. Despite their random fluctuations there existed some compensatory relationship between the percentages of the III- and IV-group fish, but only in the nets with meshes of 2⅜ to 2¾ inches. In these nets each decrease in the relative abundance of the former group was accompanied by an increase in this abundance of the latter and vice versa. This more or less constant relationship is also evidenced by the average age of the two groups, which fluctuated very little, at random, from 3.6 to 3.7 years. The tendency for each larger mesh to take more older trout is expressed by the average age of groups II to VII, which increased progressively from 3.7 years for the fish caught in 2⅜-inch meshes to 4.6 years for those captured in the 3-inch meshes.

The central Green Bay samples (Menominee and Green Island) showed characteristics and trends that varied from those of the other ports of the lake (table 11). They contained fewer age groups (III–V), relatively many more III-year fish, comparatively fewer IV-year individuals, and practically no V-year trout. Inasmuch as only 13 Green Island trout were aged and only two sizes of mesh were employed in taking them on September 23, 1930, this sample need not be considered here. It did agree with the Menominee collection of 1932 in show-

ing strong dominance (77 percent) by the III-year fish.

Age group III, the youngest fish taken, dominated strongly (73 to 87 percent) all of the Menominee lifts of May 10, 1932, except those taken in meshes of 2¾ inches where the III- and IV-year fish were nearly equal in number (46 and 49 percent). Age groups III and IV made up the bulk of the take in all nets, supplying from 94 to 99 percent (average 97) of the individuals. Only 3 percent of the entire sample consisted of V-year fish, the oldest taken.

In each group of nets, except those with meshes of 2¾ inches, there was a consistent and progressive decrease in the percentage of abundance with each increase in the age of the fish. There was also a progressive decrease in the percentage of occurrence of the III-group with each increase in the size of mesh and a progressive increase in this percentage with increased mesh size in the IV-group. The increasing percentages of age group IV more or less compensated for the decreasing percentages of group III. The change with each larger mesh ultimately led to a shift in dominance in the 2¾-inch-mesh nets from the III- to the IV-year fish. This change was also evidenced by the gradual and progressive increase in the average age of the trout from 3.1 to 3.6 years.

In order to learn whether our results on the selectivity of the different meshes (table 29) could be explained by variations in age composition, we must have some information on the age groups that composed or at least dominated the total lifts. We should know whether our samples of aged trout adequately represented the total catches. One method of approach to this problem would be to compare, for nets with corresponding meshes, the average lengths of all fish taken in the various regions (table 22) with those of the aged fish (table 12) and from the nearness of their agreement determine the probable age groups in the total catch.

These comparisons show that the mean lengths (12.4, 13.1, 13.5, 14.1, 15.2 inches) of the trout of lower Lake Michigan taken in nets with meshes of 2⅜ to 3 inches agreed more closely with the average lengths of the two dominant age groups than with those of all groups. These facts suggest that in lower Lake Michigan age groups III and IV in the nets with meshes ranging from 2⅜ to 2¾ inches and age groups IV and V in the nets with meshes of 3 inches were more strongly represented in the total catch than in the samples.

A similar analysis for the trout of upper Lake Michigan shows that here the average lengths (13.9, 14.2, 14.7 inches) of all trout approached more closely those of all age groups than the averages of the two dominant age groups. The total catch in the two smallest meshes may have had a slightly greater representation of older trout than the samples, as suggested by the greater average lengths of all fish.

The mean lengths of the central Green Bay trout (11.5, 12.4, 13.0, 13.5 inches) consistently exceeded those of the Menominee fish, although the difference was very

Table 12.—Average total length of lake trout of each age group taken in gill nets with different sizes of mesh, 1930–32

[In inches. Sexes combined. Number of specimens shown in parentheses]

Locality and mesh size of nets	In age group—								Age groups III and IV	All groups
	II	III	IV	V	VI	VII	VIII	X		
All localities exclusive of Menominee and Green Island:										
2⅜ inches		11.9 (15)	12.9 (21)	13.4 (4)			17.2 (1)		12.5 (36)	12.7 (41)
2½ inches	12.2 (3)	12.8 (32)	13.4 (69)	14.7 (18)	18.7 (3)	19.6 (2)			13.2 (101)	13.6 (127)
2⅝ inches	12.4 (1)	13.2 (42)	13.6 (66)	15.1 (21)	18.0 (9)				13.4 (108)	14.0 (139)
2¾ inches	12.8 (2)	13.6 (47)	14.6 (107)	15.6 (34)	17.4 (9)	19.9 (3)		27.0 (1)	14.3 (154)	14.8 (203)
3 inches		13.6 (4)	14.5 (22)	15.4 (30)	17.8 (4)	20.0 (4)	22.3 (1)		[1] 15.1 (52)	15.6 (65)
All sizes	12.4 (6)	13.1 (140)	14.0 (285)	15.2 (107)	17.8 (25)	19.9 (9)	19.8 (2)	27.0 (1)		14.3 (575)
Menominee, Mich., May 10, 1932:										
2⅜ inches		11.4 (61)	12.0 (8)	12.8 (1)					11.4 (69)	11.4 (70)
2½ inches		11.6 (49)	12.8 (9)	13.8 (2)					11.8 (58)	11.9 (60)
2⅝ inches		12.2 (30)	12.8 (10)	13.7 (1)					12.4 (40)	12.4 (41)
2¾ inches		12.5 (16)	12.9 (17)	13.1 (2)					12.7 (33)	12.7 (35)
All sizes		11.7 (156)	12.7 (44)	13.4 (6)					11.9 (200)	12.0 (206)

[1] Age-groups IV and V; III and IV=14.4 (26).

small (0.1 inch) in the specimens taken in the 2⅜-inch meshes. The total catch in the three largest meshes must have included a greater percentage of the older fish than were represented in the Menominee sample.

The analyses of average lengths indicate that with the exception of the Green Bay fish the age composition of the total catches and the samples of the aged trout were in all probability dominated by the same age group. The strong similarity or disagreement between the total catches and the samples may also be brought out by comparing the corresponding length frequencies of all captured trout and of the aged fish.

In table 13 we have, for brevity, restricted our comparisons to the most critical data, that is, to those 2-inch length intervals that dominated all trout taken in the specific nets indicated. The data show the percentages by number of these fish in their respective collections. With one exception the figures always represented more than 55 percent of the total catch or samples involved. Comparisons for the various meshes again indicate very good agreement everywhere except in central Green Bay where the differences in the percentages ranged from 8 to 20 in the three largest meshes; the other discrepancies never exceeded 6. The greater differences among the Green Bay fish resulted largely from the absence in the sample of aged specimens of the 14.0–14.9 length class which was well represented in the total catch. The relatively low percentage of the Green Bay aged specimens taken in the 2⅝-inch mesh was caused by a decided shift

Table 13.—Comparing the percentages of the number of all trout and of aged trout found in the length class that dominated the total catch of gill nets

Total length	Mesh 2⅜ inches		Mesh 2½ inches		Mesh 2⅝ inches		Mesh 2¾ inches		Mesh 3 inches	
	All fish	Aged fish	All fish	Aged fish	All fish	Aged fish	All fish	Aged fish	All fish	Aged fish
Lower Lake Michigan, 1930–31:										
11.0–12.9 inches	70	66								
12.0–13.9 inches			65	63	63	58				
13.0–14.9 inches							60	57		
14.0–15.9 inches									56	52
Upper Lake Michigan, 1932:										
12.0–13.9 inches			57	63						
13.0–14.9 inches					57	58	60	57		
Central Green Bay, 1932:										
10.0–11.9 inches	79	80								
11.0–12.9 inches			66	78						
12.0–13.9 inches					74	66	68	88		

(the only one) in the dominant group. Whereas the total catch was dominated by fish 12.0–13.9 inches long, the aged trout were dominated by those 11.0–12.9 inches in length.

As a further check and in order to obtain more specific data on the age groups of the total catches, we may follow another method of approach; we may compute for the bulk of the aged specimens the percentage age composition in each 1-inch interval of total length and then apply this percentage to the total number of captured individuals recorded for the corresponding interval. From 88 to 94 percent of all trout taken in the different meshes from the main lake were covered in these computations; 72 to 97 percent of those caught in Green Bay were included, the percentage of the Bay fish decreasing progressively with each increase in the size of mesh (table 14). Thus, the bulk of all total catches was covered and the estimated average percentages should, therefore, represent adequately all of the fish. The condensed data are shown in table 14 for the different regions of the lake.

In lower Lake Michigan the total catch of the 2⅜-inch-mesh nets was, according to the computations of this table, actually dominated by age group III instead of IV as in the sample of aged trout, although the difference in relative abundance between the two groups was not large (46 and 41 percent). In the lifts of the nets with meshes of 2½ to 2¾ inches age group IV was dominant (group III ranked second), and with meshes of 3 inches the V-group ranked first, group IV second. These results agreed with those based on the samples of aged fish.

The data of table 14 now give us an explanation (not fully provided by the samples of aged fish) as to why the average number of trout per net remained practically constant in lower Lake Michigan for those nets with meshes of 2½, 2⅝ and 2¾ inches but was reduced in the nets with meshes of 2⅜ and 3 inches (see Lower Lake Michigan 1930–31, table 29). The age composition of the total catch in the

Table 14.—Showing for nets of each mesh size and for different length intervals the computed total catch of each age group for the various regions of the lake

[Percentage age composition shown in parentheses]

Mesh size	Range of lengths (inches)	Percentage of total catch covered	Aged fish (number)	Computed total catch of age group				
				III	IV	V	VI	III–VI
Lower Lake Michigan, 1930–31:								
2⅜ inches	10.0–13.9	90	33	592 (46)	530 (41)	156 (12)	0 (0)	1,278
2½ inches	11.0–14.9	91	109	583 (37)	883 (56)	120 (8)	0 (0)	1,586
2⅝ inches	11.0–15.9	94	124	657 (38)	884 (51)	176 (10)	13 (1)	1,730
2¾ inches	12.0–15.9	88	166	541 (34)	877 (54)	171 (11)	20 (1)	1,609
3 inches	13.0–16.9	84	54	86 (6)	532 (39)	719 (52)	34 (2)	1,371
Upper Lake Michigan, 1932:								
2½ inches	12.0–15.9	88	111	204 (23)	540 (62)	126 (14)	0 (0)	870
2⅝ inches	12.0–16.9	94	128	284 (28)	516 (50)	189 (18)	36 (4)	1,025
2¾ inches	12.0–16.9	92	181	236 (25)	537 (56)	156 (16)	23 (2)	952
Central Green Bay, 1932:								
2⅜ inches	10.0–12.9	97	70	332 (87)	43 (11)	5 (1)	0 (0)	380
2½ inches	10.0–13.9	92	59	536 (71)	166 (22)	51 (7)	0 (0)	753
2⅝ inches	10.0–13.9	85	41	368 (59)	249 (40)	3 (1)	0 (0)	620
2¾ inches	10.0–13.9	72	35	218 (41)	277 (53)	31 (6)	0 (0)	526

nets with the three intermediate sizes of mesh differed very little, that is, the relative representation of the three principal age groups (III, IV, and V) remained approximately constant. All three meshes therefore drew upon the same stocks or groups of fishes. Since the catches of the nets with meshes of 2⅜ and 3 inches were dominated by the smaller age groups (III or V), the average take per net was also smaller than that of the nets with the three intermediate sizes of mesh where the large IV-group dominated.

This last statement with respect to the numerical size of age groups in the lake needs further clarification. It is difficult to determine with absolute certainty by the use of gill nets, even though several sizes of mesh are employed, whether dominant age groups represent the actual abundance of the fish in the lake or simply represent the groups that are most vulnerable to the mesh sizes. However, our data suggest that the trout of age group IV were actually more abundant in the lake than those of age group III or V.

The length frequency data (table 23) indicate that fish 11.0–11.9 inches long were most vulnerable to the 2⅜-inch meshes in the lake proper. Inasmuch as the average length of the III-group was found to be 11.7 inches (p. 43) these fish should then dominate strongly this length class. Computations show that 67 percent of this class were III-year fish. On the basis of the position of the average length within the length interval we should also expect to find a considerable number of the 3-year fish in the next higher length class (12.0–12.9 inches) which ranked second in

vulnerability. Computations indicate that 42 percent of these trout should belong to this age group.

Applying these percentages to the total numbers of fish in their respective length classes (553 and 431, table 23) taken in the 2⅜-inch-mesh nets, we find from the combined estimates that 551 of the 984 trout or 56 percent should be III-year individuals. Age group III would then dominate the two combined length classes. Checking this estimated percentage with the actual based on the computed numbers for these length classes (983 fish), we observed that only 43 percent (427 fish) belonged to age group III and that 54 percent (530 fish) belonged to group IV. These figures indicate that the IV-group trout were more abundant in the lake than the III-group.

Employing the same technique to obtain percentages for the IV-year fish, we find that these trout with an average length of 13.0 inches were most vulnerable to nets with meshes of 2⅝ inches. They should dominate the two combined length classes of 12.0–12.9 and 13.0–13.9 inches. It was ascertained that 55 percent of the former length class and 53 percent of the latter theoretically belonged to age group IV. Of the total of 1,167 fish in these two length classes 630 or 54 percent should then be 4 years old.

Checking for the corresponding length classes this estimated percentage with the actual, again derived from the computed numbers, we found a very close agreement, 56 percent (642 fish) as compared with 54 (630 fish). Here the IV-group actually dominated the catch as expected. Age group III should have done so also in the smaller mesh nets if it had actually been the most abundant in the lake. That the 2⅜-inch meshes can take considerable numbers of trout 11.0–11.9 inches long that belong to age group III is evidenced by the length-frequency records for Green Bay (table 23) where 87 percent (table 11) of the fish caught in this mesh were 3 years old.

Inasmuch as the same fishing effort was used for both the 2⅜- and 2⅝-inch-mesh nets and the III-group fish were most vulnerable to the former nets and IV to the latter, the total numbers caught of the length classes considered above should give us another clue to the relative actual abundance of each age group in the lake. As indicated above, the computed actual catch of the III-year fish was 427 as compared with 642 of the IV-group. According to these data the IV-year trout were 50 percent more abundant than the III-year. Whether or not this percentage is only a rough estimate of the difference in numbers, it at least indicates a predominance of the older fish and confirms the same conclusion derived previously by a different method of analysis.

Continuing our analysis we find on the basis of average length (14.4 inches) that the V-year trout should be most vulnerable to the 3-inch-mesh nets. Computations show, however, that 45 percent of the fish 14.0–14.9 inches long taken in these nets belonged to age group V and 50 percent to group IV. These data testify once more to

the greater abundance of the IV-year trout.

As was true for the lower lake in 1930–31, so also in the upper lake in 1932 age group IV dominated the entire catch taken in the nets with meshes of 2½, 2⅝, and 2¾ inches; age group III ranked second, V third. The V-year fish were relatively more abundant in the 1932 lifts than in those of 1930–31. This increase was made at the expense of the III-group; the 1932 percentages of the IV-year trout did not vary much from those of the preceding years. Except for these differences in relative abundance, the age composition of the trout of upper and lower Lake Michigan was the same. A similar conclusion was also derived from the data of the aged trout (p. 20). The approximate constancy of the relative abundance of the three principal age groups again explains the slight differences in the catch of those nets with different meshes employed in the upper lake (table 29).

In central Green Bay age group III ranked first, IV second, in the total catch of those nets with meshes of 2⅜–2⅝ inches, but the reverse was true for the 2¾-inch-mesh nets (the same situation was found among the aged fish). Except in the smallest mesh, the percentages of the IV-group trout consistently were larger and of the III-group smaller in the total catch than in the Menominee sample (table 11). It is unfortunate that Green Bay specimens 14.0–14.9 inches in length, which were taken in moderate numbers with meshes of 2⅝ and 2¾ inches (table 23), were unavailable for age determination. The inclusion of these individuals would undoubtedly have raised the percentages of groups IV and V in the aged fish of these nets but not to the extent that the age composition would have been changed very much.

There was no constancy in the relative abundance of the two dominant age groups in the different group of nets in either the total catch or the samples. The percentage of the III-year trout decreased and that of the IV-year fish increased with each enlargement of the mesh. These facts explain why the average catch of the nets with different meshes did not remain more or less constant in Green Bay as it did in the main lake. As the large group of III-year fish (in contrast to the main lake the III-group trout outranked the IV in central Green Bay because of the large run of young fish in the spring; see p. 70) decreased in relative abundance and was replaced by the older and scarcer trout, the average take per net was bound to diminish. Such a reduction actually took place. The catch per net declined progressively with each increase in the size of the mesh from 2⅜ to 2¾ inches as follows: 11.6, 8.1, 6.4, 5.5.

In résumé, we may conclude that the computed data for the total catch varied from those of the aged trout mainly in showing for the lake proper dominance by group III instead of IV in the 2⅜-inch-mesh nets and a generally stronger representation of the two principal age groups and for Green Bay a better

representation of the older individuals. Because these differential characteristics offer a fuller explanation of the results on the selectivity of the different meshes, the total-catch figures (table 14) should be given preference to the aged-fish data (table 11). It should be pointed out, however, that except for the fish caught in the 2⅜-inch-mesh nets the dominant age groups and age composition were the same in the samples of aged trout and the total catches.

CALCULATED INCREMENTS OF LENGTH

Calculations of growth based on body lengths and scale measurements may vary with the size of mesh in nets, locations, seasons, years, age of fish, year class, and other factors, especially in such large bodies of water as the Great Lakes. Such variables should be considered whenever they are involved in a combination of computed measurements of growth. We have, therefore, attempted to evaluate these factors whenever possible before consolidating the calculations of growth of the Lake Michigan lake trout.

Variation with mesh

To ascertain what effect the size of the mesh of our gill nets had on the computed lengths of the trout, we employed the two dominant age groups (III and IV) of our two largest collections (Menominee and Charlevoix). The data shown in table 15 reveal that, although the total lengths at capture had increased with each enlargement in the size of the mesh in the well-represented age groups, the calculated lengths (and increments) followed no fixed pattern; they varied at random. They may, therefore, be combined irrespective of the mesh size.

Variation with ports

It was determined next whether it would be valid to combine the growth data of the trout from several ports within a region by age group and calendar year. In table 16 are compared the calculated annual increments of length of trout

Table 15.—Total lengths at capture and calculated total lengths of lake trout, by age group and by sizes of mesh employed in their capture

[Lengths in inches. Number of specimens shown in parentheses]

Locality and mesh size	Age group	Length at capture	Calculated length for year—		Age group	Length at capture	Calculated length for year—		
			1	2			1	2	3
Menominee, Mich., May 10, 1932:									
2⅜ inches	III (61)	11.4	3.4	7.5	IV (8)	12.0	3.5	6.4	8.8
2½ inches	III (49)	11.6	3.3	7.4	IV (9)	12.8	3.4	7.2	10.0
2⅝ inches	III (30)	12.2	3.7	8.2	IV (10)	12.8	3.5	7.2	9.8
2¾ inches	III (16)	12.5	3.7	8.0	IV (17)	12.9	3.4	7.2	10.2
Charlevoix, Mich., July 30, 1932:									
2½ inches	III (16)	13.0	3.9	7.6	IV (20)	13.8	3.5	7.0	9.7
2⅝ inches	III (26)	13.4	3.6	7.4	IV (22)	14.0	3.2	6.5	9.2
2¾ inches	III (18)	13.8	4.0	8.0	IV (25)	14.7	3.3	6.9	9.8

Table 16.—Calculated increments of length of lake trout from different Lake Michigan ports compared for each of three age groups taken with the same sizes of mesh in the same year

Port	Year	Age group	Number of fish	Increment of length (inches) for year—					Total increment (inches)
				1	2	3	4	5	
Kenosha-Racine	1930	III	10	3.4	3.4	3.3			10.1
Ludington	1930	III	12	3.7	3.9	3.0			10.6
Racine	1931	III	7	3.9	3.5	3.2			10.6
Sheboygan	1931	III	9	3.4	4.2	3.5			11.1
Kewaunee	1931	III	19	4.9	3.7	2.8			11.4
Charlevoix-Leland	1932	III	70	3.8	3.8	2.9			10.5
Manistique	1932	III	15	4.1	3.7	2.8			10.5
Kenosha-Racine	1930	IV	15	3.0	3.1	3.3	2.6		12.0
Ludington	1930	IV	22	3.9	3.0	3.0	2.5		12.4
Racine	1931	IV	27	2.5	3.2	3.3	2.7		11.7
Sheboygan	1931	IV	26	2.9	3.3	3.0	2.4		11.6
Kewaunee	1931	IV	45	3.1	3.5	3.1	2.3		12.0
Charlevoix-Leland	1932	IV	94	3.4	3.6	2.8	2.3		12.1
Manistique	1932	IV	49	3.4	3.9	2.7	2.8		12.8
Kenosha-Racine	1930	V	8	3.3	2.9	3.0	2.5	2.1	13.8
Ludington	1930	V	9	2.9	3.4	2.9	2.5	1.9	13.6
Racine	1931	V	11	3.1	3.0	2.8	2.6	1.9	13.4
Sheboygan	1931	V	20	3.0	3.3	2.9	2.4	2.2	13.8
Kewaunee	1931	V	14	2.8	2.8	3.0	2.4	1.8	12.8
Charlevoix	1932	V	15	3.1	3.3	3.0	2.5	2.0	13.9
Manistique	1932	V	29	3.1	3.6	2.9	2.6	2.2	14.7

that belonged to the same age group and year class and were caught with the same combination of mesh sizes in the same year but at different ports on Lake Michigan proper. The number of specimens available for some of the comparisons is rather small. The data show a tendency for the increments to vary with the ports. There was a definite trend for the annual growth rates of the first two years of life to increase with a change in latitude from south to north but only in age groups III and IV. In the third and later years the trend was sharply reversed. Fifteen of the 20 comparisons for the first and second year of groups III and IV followed the trend. Of the 15 comparisons for the next three years only 3 agreed with the trend.

These records indicate that the faster growing fish of the more northerly waters became the slower growing individuals, usually after they passed their second year of life. This reversal means that in general any advantage in growth that a young lake trout had was only a temporary one. It usually required more than one year of reversal in growth rate to affect the trend of the computed total lengths, at least in those age groups that were investigated (see last column of table 16).

Since the tendency of growth to vary with latitude was not observed in age group V and small numbers of specimens were employed for some of the averages, there may be a question whether the recorded differences between the growth of those trout that did show an increase with latitude were really significant. We may check this question by comparing the calcu-

lated increments of trout taken on different dates of the same year but from the same port (table 17). The numbers of trout employed in this table are of about the same magnitude as those used in table 16.

The discrepancies of table 17 fluctuated at random with the years of life and with the age groups. It is of interest to note here that even in the fish from the same port (Manistique) there was a decided trend in both age groups, with consistent increases in the later samples in the first two years of life and a reversal thereafter. The trends in the data of table 16, therefore, need not necessarily be significant, especially if the differences are small. Computations show that the average of the differences shown in table 17 equaled 10 percent of the average increment for the first two as well as the next two years of life. In other words, a decrease or increase of 10 percent in the mean increment should not be given much consideration.

If we apply this criterion to those averages of age groups III and IV (table 16) that showed increases during the first two years of life, we find that only 7 out of the 15 comparisons or 47 percent indicated significant differences. All of them were isolated occurrences, never found consistently between the same ports, nowhere followed by similarly significant discrepancies but often by a difference reversed from a minus to a plus value or vice versa (see e. g. group III, 1931). It appears, then, that despite any trends the variations in the growth rates of the trout caught out of different ports in the two main regions of the lake proper can not be considered significant. It seems valid, therefore, to combine the growth data of fish from different ports in order to make comparisons with the Green Bay trout and to examine the differential growth of the year classes. The subsection on variation with year classes (p. 39) provides evidence that growth in upper Lake Michigan did not differ significantly from that in the lower lake.

In table 18 growth rates of trout from the upper lake and central Green Bay are compared for cor-

Table 17.—Comparisons of calculated increments of length of lake trout taken at the same port on different dates in 1932

Port and date	Age group	Number of fish	Increment of length (inches) for year—				
			1	2	3	4	5
Manistique:							
June 15	IV	21	3.4	3.6	3.0	2.9	
Aug. 31—Sept. 1	IV	28	3.5	4.0	2.6	2.7	
Difference			0.1	0.4	0.4	0.2	
Charlevoix:							
July 30	IV	72	3.3	3.5	2.8	2.3	
Aug. 13	IV	10	3.2	4.1	3.0	2.2	
Difference			0.1	0.6	0.2	0.1	
Manistique:							
June 15	V	20	2.9	3.5	3.0	2.7	2.
Aug. 31—Sept. 1	V	9	3.4	3.9	2.7	2.4	2.
Difference			0.5	0.4	0.3	0.3	0.

Table 18.—Comparisons of growth rates of lake trout from upper Lake Michigan and central Green Bay employing fish of the same age and year class

Section of lake	Year of capture	Age group	Year class	Number of fish	Increment of length (inches) for year—				
					1	2	3	4	5
Lake Michigan	1932	III	1929	85	3.8	3.8	3.0	------	------
Green Bay	1932	III	1929	156	3.5	4.2	3.7	------	------
Lake Michigan	1932	IV	1928	143	3.4	3.7	2.8	2.4	------
Green Bay	1932	IV	1928	44	3.4	3.7	2.7	2.6	------
Lake Michigan	1932	V	1927	44	3.1	3.5	2.9	2.6	2.2
Green Bay	1932	V	1927	6	3.6	3.4	1.8	2.5	2.1

responding age groups and year classes. With one exception (third year of group III; the 6 five-year-olds are not considered) no differences exceeded the critical 10 percent (the 4-year fish were in almost perfect agreement) and any advantage in growth shifted between the fish of these two regions. It may be concluded, then, that the variation in the growth rates of these trout was not significant.

Variation with year classes and calendar years

The average calculated increments of length of five year classes (1929, 1928, 1927, 1926, 1925) from the main lake are presented in table 19. Comparisons are made only between trout of the same age group. There was little difference in the growth rates of the 1929 (upper lake) and 1927 (lower lake) year classes. The 1928 fish appear to have had a better growth than some of the other individuals in the first year of life as group III and in the first and second as group IV. No consistent differences existed between the rates of the 1927 and 1926 fish of groups IV and V, and no significant variations occurred between these two year classes and the 1925 fish. It appears that the trout of all of these year classes grew at about the same rate except those of 1928 as indicated above. Nowhere else were the larger discrepancies consistent in all age groups.

To ascertain whether the larger averages of the 1928 year class were related to some particular year, we rearranged the increments of each age group according to calendar years. Comparisons showed that no single year stood

Table 19.—Comparisons of calculated increments of length of lake trout from Lake Michigan proper (1930–32) that belonged to different year classes

Year class	Section of lake	Age group	Number of fish	Increment of length (inches) for year—				
				1	2	3	4	5
1929	Upper	III	85	3.8	3.8	3.0	------	------
1928	Lower	III	35	4.3	3.8	3.1	------	------
1927	Lower	III	22	3.6	3.7	3.0	------	------
1928	Upper	IV	143	3.4	3.7	2.8	2.4	------
1927	Lower	IV	97	2.9	3.3	3.2	2.4	------
1926	Lower	IV	37	3.5	3.1	3.1	2.5	------
1927	Upper	V	44	3.1	3.5	2.9	2.6	2.2
1926	Lower	V	45	2.9	3.1	3.0	2.4	2.0
1925	Lower	V	17	3.0	3.2	3.0	2.5	2.0

out consistently as one of unusually poor or good growth. The larger averages were apparently fortuitous and not significant. It seems valid, then, to conclude that no important differences existed in the growth rates of the five year classes. The data on growth may be combined for all Lake Michigan (including Green Bay) trout according to age (table 20).

Variation with age

The increments of only the three largest age groups (III, IV, V) have been presented in the lower part of table 20 for a study of variation in growth rate with age. These groups were represented in all samples except two small ones collected off Leland, Mich., and Green Island in Green Bay. The data may be considered strictly comparable for an analysis of the variability of growth with age. This study can be carried out only through the fourth year.

The average increments decreased progressively with increase in age during the first two years of life. In the third year there was still a decline between the III- and IV-year fish but the two oldest groups grew at the same rate in this as well as the fourth year. The changing trends point to the possible presence of Lee's "phenomenon of apparent change in growth rate." The inadequate numbers of fish older than 5 years make it impossible for us to follow the trend to its ultimate development. Although the discrepancies between the increments of two successive age groups may not have been significant they did grow in importance as the difference between the ages increased.

To obtain a general picture of growth we combined the calculations of total length of all fish in the collections and by simple subtractions derived from these grand averages the increments of length. The figures are shown at the bottom of the table. They indicate that the trout reached a length of about 3.4 inches in the first year, then added another 3.7 inches in the second year, and thereafter grew progressively less rapidly each year through the fifth. The number of specimens in our samples was too small to provide stable averages for the sixth and later years. (For the final average increments of length see p. 43).

In résumé, we may conclude (1) that the calculated increments and computed lengths of the young lake trout were not influenced by the size of mesh in which they were captured, (2) that the growth rates did not vary significantly in the different regions of the lake, or (3) with the year classes, or (4) with the calendar years, (5) that the calculated increments varied with age suggesting the presence of Lee's phenomenon, and (6) that the annual growth rate based on calculated total lengths declined progressively after the second year through at least the fifth (the final preferred increments, however, did not follow this trend, p. 43).

CALCULATED TOTAL LENGTHS

The increments rather than total lengths were employed in analyzing growth (except in the subsection on variation with mesh) because they brought out more clearly the actual differences between the annual rates and the actual fluctuations from year to year. Total lengths obscure the actual growth rates. We are, however, also interested in learning the size that trout reach at various ages. The data on computed total lengths have been combined for all fish in table 20. Inasmuch as age influenced the computations of growth, we can probably obtain the best general figures by averaging the total lengths of each year for all age groups. These means are given near the bottom of the table. They show that the trout reached the following computed lengths in inches during the first 5 years of life: 3.4, 7.1, 10.1, 12.1, and 14.0.

Table 20.—Calculated total lengths and increments of length of lake trout collected from Lake Michigan and central Green Bay, 1930–32

[In inches. Green Bay samples included only individuals from age groups III, IV, and V]

Item	Number of fish	Calculated total lengths and increments for year—									
		1	2	3	4	5	6	7	8	9	10
Calculated total lengths for—											
Age group II	7	5.1	8.8								
Age group III	309	3.7	7.6	11.0							
Age group IV	340	3.3	6.8	9.7	12.2						
Age group V	115	3.0	6.3	9.2	11.7	13.8					
Age group VI	28	3.2	6.7	9.8	12.3	14.6	17.0				
Age group VII	9	3.0	6.0	9.0	11.9	14.0	16.3	18.7			
Age group VIII	2	3.5	6.8	9.4	11.3	13.2	14.9	16.9	18.5		
Age group X	1	3.9	8.0	10.3	13.3	15.6	18.8	21.0	23.0	25.0	27.0
Calculated increments of length for—											
Age group III	309	3.7	3.9	3.4							
Age group IV	340	3.3	3.5	2.9	2.5						
Age group V	115	3.0	3.3	2.9	2.5	2.1					
Grand averages:											
Lengths		3.4	7.1	10.1	12.1	14.0	16.8	18.6	20.0	25.0	27.0
Increments		3.4	3.7	3.0	2.0	1.9	2.8	1.8	1.4	5.0	2.0
Total number of fish	811	811	811	804	495	155	40	12	3	1	1

AVERAGE LENGTHS AND WEIGHTS AT CAPTURE OF TROUT OF DIFFERENT AGE GROUPS

The average total lengths (inches) and weights (ounces) of the trout at capture are shown in table 21 for each age group taken off different ports of Lake Michigan. The data have been combined for all nets irrespective of the sizes of mesh that were employed in taking the sample. Inasmuch as the same combination of meshes was used for the lower-lake collections in 1930 and 1931 and these fish were taken late in the growing season, weighted grand averages (near bottom of table) were obtained for them which, comparisons show, represented very well the values for each port. These grand averages represent the lengths and weights of fish that have completed almost one more season's growth than is indicated by the ages shown in the table. Thus the average length (12.6 inches) of age group III

Table 21.—Average total length and weight at capture of the lake trout of each age group from various localities in Lake Michigan

[Sexes combined. Length in inches. Weight in ounces]

Item	For age group—							
	II	III	IV	V	VI	VII	VIII	X
Kenosha, Nov. 10, 1930, mesh 2⅜–3 inches:								
Length	7.2	12.0	13.4	15.3	19.8			
Weight	1.8	7.7	10.5	16.3	38.0			
Number	1	4	12	3	3			
Racine, Aug. 8, 1930, mesh 2⅜–3 inches:								
Length	12.3	11.9	13.9	16.3	20.7		17.2	
Weight	10.0	7.4	13.5	22.2	36.0		24.8	
Number	1	6	3	5	1		1	
Racine, Oct. 21, 1931, mesh 2⅜–3 inches:								
Length		12.4	13.1	15.1	17.6			
Weight		9.0	10.2	16.6	25.5			
Number		7	27	11	2			
Sheboygan, Nov. 18, 1931, mesh 2⅜–3 inches:								
Length	12.4	12.6	13.1	15.4	19.5	20.0	22.3	
Weight	7.5	9.1	10.0	16.3	35.4	41.0	47.0	
Number	1	9	25	20	4	4	1	
Kewaunee, Nov. 19, 1931, mesh 2⅜–3 inches:								
Length	13.0	13.1	13.7	14.4	18.0			
Weight	10.2	9.5	11.2	13.1	25.6			
Number	1	19	45	14	2			
Ludington, Aug. 13, 1930, mesh 2⅜–3 inches:								
Length	12.2	12.5	14.4	15.1	18.8			
Number	2	12	22	9	1			
Leland, Aug. 16, 1932, mesh 2¾ inches:								
Length		13.9	15.1		19.4			
Weight		10.5	14.3		30.0			
Number		6	12		1			
Charlevoix, July 30, 1932, mesh 2½–2¾ inches:								
Length	12.6	13.4	14.2	15.8				
Weight	8.0	10.0	11.8	16.7				
Number	1	63	72	14				
Charlevoix, Aug. 13, 1932, mesh 2¾ inches:								
Length		15.3	14.5	15.1				
Weight		16.0	12.4	13.5				
Number		1	10	1				
Manistique, June 15, 1932, mesh 2½–2¾ inches:								
Length		12.6	13.2	14.6	16.9	19.2		27.0
Weight		8.1	9.8	13.3	22.0	34.1		90.5
Number		3	21	20	12	4		1
Manistique, Aug. 31 Sept. 1, 1932, mesh 2¾ inches:								
Length		13.3	15.0	16.4	17.0	21.9		
Weight		9.8	13.3	19.7	21.5	54.0		
Number		12	28	9	2	1		
Escanaba, May 26, 1932, mesh 2½–2¾ inches:								
Length		12.9	14.0	14.2				
Weight		9.0	11.5	12.1				
Number		1	16	3				
Menominee, May 10, 1932, mesh 2⅜–2¾ inches:								
Length		11.7	12.7	13.4				
Weight		7.3	9.1	10.6				
Number		156	44	6				
Green Island, Sept. 23, 1930, mesh 2½–2⅝ inches:								
Length		12.1	12.8					
Weight		8.4	9.2					
Number		10	3					
Lower lake, 1930–31, mesh 2⅜–3 inches:								
Length	11.6	12.6	13.6	15.1	19.1	20.0	19.8	
Number	6	57	134	62	13	4	2	
Weight	7.4	8.9	10.7	16.1	32.8	41.0	35.9	
Number	4	45	112	53	12	4	2	
Entire lake, 1930–32 (table 20):								
Calculated length	10.1	12.1	14.0	16.8	18.6	20.0	25.0	
Number	804	495	155	40	12	3	1	

tually represents nearly 4 years growth. (That the seasonal owth was not completed by all these trout was indicated by the rcentages of table 10.) The data r the other collections may not combined because they were ken at different times during the tive growing season or with differ- t meshes. Since a greater variety meshes was employed in the wer lake, the specimens from ese waters probably give the best verage on the actual average ngths and weights of trout at fferent ages.

The grand averages reveal that ear the end of the fourth summer ie fish averaged 12.6 inches, of the th 13.6, and of the sixth 15.1 ches. Corresponding weights in nces were: 8.9, 10.7, and 16.1. took these trout more than 5½ ears to reach 1 pound in weight. ot enough specimens were avail- ble to supply trustworthy data eyond the sixth summer.

It is of interest to compare the tual lengths of these trout with ie nearly comparable calculated values. The computed lengths are given at the bottom of the table. These lengths, of course, represent full-year growths in contrast to the corresponding actual lengths. The former should, therefore, exceed the latter, which actually happened in two of the three age groups that included the greatest number of specimens. On the whole the agreements between the actual and calculated lengths may be considered good where large numbers of specimens were employed.

Considering now our best data from various sources, both calculated and actual measurements (tables 6 and 20), we may conclude in summarizing our results that the various age groups of the lake trout of Lake Michigan reached approximately the following average total lengths in inches at the end of a completed year of life: I–3.4, II–7.1, III–11.7, IV–13.0, V–14.4, VI–16.8, VII–18.6. The annual increments of growth obtained from these lengths for the first 7 years of life are, respectively, 3.4, 3.7, 4.6, 1.3, 1.4, 2.4, and 1.8 inches.

AVERAGE LENGTHS, WEIGHTS, AND LENGTH FREQUENCIES OF TROUT TAKEN IN DIFFERENT MESHES

The average total length in inches nd weight in ounces of lake trout aught in gill nets with different zes of mesh are shown in table 22 r Lake Michigan and Green Bay. he averages of weight are based n the bulk-weight of the enumer- ted fish of entire lifts (catches ere weighed in bulk and counted) ut those of length are founded on ie field measurements of either the entire lift or of large samples from these lifts.

The table reveals that the average length and weight of the trout increased with each enlargement of the mesh in all years and in all sections of the lake. In lower Lake Michigan where all five meshes were used these averages ranged from 12.4 inches and 8.8 ounces for fish taken in the 2⅜-inch-mesh nets

Table 22.—Average total length and weight of lake trout caught in gill nets of different mesh sizes, Lake Michigan, 1930–32

[Length in inches. Weight in ounces]

Item	Number of fish	In stretched mesh of—				
		2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches
East shore:						
1930:						
Length	718	12.2	13.1	13.5	13.8	14.6
Weight	1,146	8.9	10.9	11.7	14.9	17.0
1931:						
Length	4,214	12.5	13.1	13.6	14.1	15.2
Weight	4,884	9.2	10.6	11.8	13.6	17.0
West shore:						
1930:						
Length	554	12.0	12.8	13.7	14.4	15.2
Weight	599	8.2	10.3	13.3	14.9	18.9
1931:						
Length	3,119	12.3	13.0	13.4	14.2	15.5
Weight	3,505	8.6	10.4	11.5	14.2	19.1
Lower Lake Michigan: 1930–31:						
Length	8,605	12.4	13.1	13.5	14.1	15.2
Weight	10,134	8.8	10.5	11.8	14.0	17.8
Upper Lake Michigan: 1932:						
Length	3,139	----------	13.9	14.2	14.7	----------
Weight	3,282	----------	11.7	12.8	14.2	----------
Central Green Bay: 1932:						
Length	2,670	11.5	12.4	13.0	13.5	----------
Weight	2,685	6.6	8.4	9.7	10.9	----------

to 15.2 inches and 17.8 ounces for those caught in the 3-inch-mesh nets. The progressive increase in the size of the trout is the result not only of the selective action of the meshes but also of the shift in the age composition of the fish. As shown in table 11 the largest percentage of III-year fish was taken in the 2⅜-inch-mesh nets, the smallest in the 3-inch, and the largest percentage of the V-group was caught in the latter nets, the smallest in the former. The table also reveals a steady increase in the percentage of trout 5 years and older (12, 18, 21, 24, and 60 percent) with each enlargement of the mesh.

To determine whether the mean sizes of the trout varied significantly with the larger geographical regions of the lake and the different years, we computed their averages for the defined east and west shores, the upper lake, and central Green Bay for the years 1930, 1931, and 1932. The data indicate that along the east shore the trout were, on the whole, slightly though rather consistently (except in the 2½-inch mesh where they averaged the same) larger in 1931 in all meshes than in 1930, but off the west coast the differences between their means of the two years fluctuated with the various meshes. Inasmuch as the discrepancies exceeded 0.3 inch only once and this difference represented an increase in length of only 3 percent, we may conclude that the average lengths of the trout taken off the same shore and in the same size mesh did not vary significantly in 1930 and 1931.

With respect to the average lengths of the trout caught along the two shores in the same year, we find that in both 1930 and 1931 the trout taken in the two smallest meshes averaged higher in the eastern than in the western areas of the lake. In the three larger

meshes, with one exception (2⅝, 1931), the reverse was true; the eastern fish averaged smaller. However, here again the discrepancies were insignificant, exceeding 0.3 inch only twice.

The trout of the upper lake consistently averaged larger in length (0.6–0.8 inch) and weight than those caught in corresponding meshes of the lower lake (data combined) whereas the fish of central Green Bay always averaged smaller in both length (0.5–1.5, average 0.95 inch) and weight than the trout in the lake proper. These differences, greater than those in the preceding paragraphs, can be explained by the variations in age composition. In the lower and upper lake the catch of the nets with meshes of 2½–2¾ inches was dominated by age groups IV and III (tables 11 and 14) although in the upper lake group V was more strongly represented than in the lower; in central Green Bay the III- and IV-year fish held first and second place, except in the 2¾-inch-mesh nets where their positions were reversed. These variations may be expressed by the average ages of the trout as determined from our samples taken from the nets with corresponding sizes of mesh (2½, 2⅝, and 2¾ inches). They were, respectively, for each region (lower, upper, Green Bay): 3.96, 4.23, and 3.32 years.

The selectivity of gill nets with respect to the size of lake trout is shown in more detail for the three sections of Lake Michigan in the length frequencies of table 23. The data of the fish taken in 1930 and 1931 off both shores of the lower lake have been combined because of their general agreement and convenience in presentation. There were two discrepancies: (1) The table conceals a difference in mode of the fish taken along the two shores in 1930 and 1931 with the 2⅜-inch-mesh nets. Among the eastern fish the mode occurred at 12.0–12.9 inches in both years or one inch larger than that shown in the table. The mode of the western fish was the same as that indicated in the table. (2) The percentage distribution of the trout above and below the mode differed in the two years. The percentages of the number of fish found in the intervals of lengths less than those of the mode were consistently higher in 1930 than in 1931. In general the reverse was true for the percentages that applied to the fish included in the modes and in those intervals of lengths greater than the modes. These facts were reflected in the averages of table 22. They need no further consideration here.

The frequency distribution of lake trout taken in each mesh in each section of the lake was uniformly unimodal and in each section there was a sufficient increase in the average size of the fish caught with each enlargement in mesh-size to cause a shift in mode, except between the 2½-inch- and 2⅝-inch-mesh nets in Green Bay and upper Lake Michigan and between the 2⅝-inch- and 2¾-inch-mesh nets in the lower lake; in the 2¾-inch-mesh of upper Lake Michigan equal numbers of fish were included in the two length intervals between 13.0 and 14.9 inches. In each of these exceptions there were shifts in the fre-

Table 23.—Length frequencies of lake trout caught in gill nets of different mesh sizes in Lake Michigan, 1930–32

Total length (inches)	Lower Lake Michigan, 1930–31							Central Green Bay, 1932						Upper Lake Michigan, 1932				
	In stretched mesh of—					Total, 2½- to 2¾-inch mesh		In stretched mesh of—				Total, 2½- to 2¾-inch mesh		In stretched mesh of—			Total, 2½- to 2¾-inch mesh	
	2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches	Number	Percent	2⅜ inches	2½ inches	2⅝ inches	2¾ inches	Number	Percent	2½ inches	2⅝ inches	2¾ inches	Number	Percent
6.0–6.9				1		1	[1] 0.0		1			1	[1] 0.0					
7.0–7.9					1				1	1		2	0.1					
8.0–8.9		2	1		1	3	0.1		2	2	2	6	0.3		1		1	[1] 0.0
9.0–9.9	2				1				3	3	6	39	1.7		2	1	3	0.1
10.0–10.9	101	22	3	7	5	32	0.6	80	30	3	6	39	1.7		2	1	3	0.1
11.0–11.9	*553*	281	116	38	9	435	7.8	*230*	239	74	24	337	14.8	42	13	3	58	1.9
12.0–12.9	431	*704*	581	306	48	1,591	28.7	70	*905*	*280*	178	761	33.4	264	191	61	516	16.4
13.0–13.9	194	491	*586*	*696*	265	*1,773*	*32.0*	10	183	263	*519*	*765*	*33.6*	*512*	*373*	313	*998*	*31.8*
14.0–14.9	64	185	331	417	*490*	933	16.8	1	46	83	148	277	12.2	195	251	*313*	759	24.2
15.0–15.9	32	70	134	220	426	424	7.6		8	12	28	48	2.1	112	138	187	437	13.9
16.0–16.9	19	32	68	83	197	183	3.3		2	8	14	24	1.0	38	77	85	200	6.4
17.0–17.9	5	18	19	40	92	77	1.4		1	2	8	11	0.5	24	26	41	91	2.9
18.0–18.9	3	7	6	25	46	38	0.7		1	2	3	6	0.3	10	9	17	36	1.2
19.0–19.9	4	2	4	9	21	15	0.3			1		1	[1] 0.0	4	7	6	17	0.6
20.0–20.9	1		5	3	10	8	0.1				1	1	[1] 0.0	3		1	4	0.1
21.0–21.9	2	7	1	6	4	14	0.3							1	5	4	10	0.3
22.0–22.9	2	3	1	4	9	8	0.1									1	1	[1] 0.0
23.0–23.9	1	1	1	1	6	3	0.1								1		1	[1] 0.0
24.0–24.9		1		1	2	2	[1] 0.0							1	1	1	3	0.1
25.0–25.9	1			3	2	3	0.1											
26.0–26.9				2	1	2	[1] 0.0									1	1	[1] 0.0
27.0–27.9					3											1	1	[1] 0.0
28.0–28.9			1		1	1	[1] 0.0							1		1	2	0.1
29.0–29.9				1		1	[1] 0.0											
30.0–30.9				2		2	[1] 0.0											
31.0–31.9					1													
34.0–34.9																		
Total	1,415	1,826	1,858	1,865	1,641	5,549	100.0	391	817	731	731	2,279	100.0	1,007	1,095	1,037	3,139	100.0

[1] Less than 0.05 percent.

quencies toward greater length, but they were insufficient to affect the mode when distribution was considered in terms of 1-inch intervals.

In lower Lake Michigan from 30 to 39 percent of the lake trout caught in the different meshes fell within the modal inch, and from 72 to 83 percent of the fish caught were within a 3-inch interval of length. The percentage for the latter interval decreased progressively with each increase in mesh size. In the other two sections of the lake a similar decrease occurred except in the 2¾-inch-mesh nets where the percentages increased. Percentages for these sections corresponding to those given above for the lower lake are: northern Lake Michigan, 30 to 34 within modes, 74 to 78 within the 3-inch interval; Green Bay, 37 to 59 within modes, 86–97 within the 3-inch interval. The Green Bay data involved only the spring lifts of 1932, not the fall catches of 1930. The closest grouping about a mode occurred in the lake trout caught in the 2⅜-inch mesh in Green Bay where 59 percent of the fish were within the modal inch and 97 percent fell within a 3-inch interval of length. Few fish of large size were taken in Green Bay during the spring netting period (only 2 fish measured more than 19 inches in length).

The modes of the frequency distributions for central Green Bay were identical with those for fish from lower Lake Michigan for three of the four meshes fished in both areas. They differed from those of fish caught in each of three comparable meshes in northern Lake Michigan if we accept the mode of the 2¾ inch-mesh nets at the greater length interval as the most logical choice for the upper lake. When data of the fish taken in the nets of the 3 mesh sizes common to all areas (2½ to 2¾ inches) are combined, the mode always occurred at the same point (13.0–13.9 inches) for all three regions with nearly identical frequency percentages (32–34). However, the distribution of the Green Bay fish about the mode for the combined meshes resembled that of lower Lake Michigan more closely than that for the more northerly area. These geographical variations can be explained by the differences in age composition (see p. 45).

It is of interest to note that the trout taken at six stations in northern Green Bay (included with northern Lake Michigan specimens in table 23) were intermediate between central Green Bay and northern Lake Michigan fish in average lengths and in length-frequency distribution. A comparison of the average total lengths in inches of individuals from the three areas follows (numbers of trout are shown in parentheses):

Area	Taken in mesh of—			Average age in years
	2½ inches	2⅝ inches	2¾ inches	
Central Green Bay	12.4 (817)	13.0 (731)	13.5 (731)	3.32
Northern Green Bay	13.2 (56)	13.5 (43)	14.2 (58)	4.10
Northern Lake Michigan.	13.9 (951)	14.2 (1,052)	14.7 (979)	4.30

Again the discrepancies were related to the age composition of the fish as is indicated by the average ages shown in the last column.

Frequency distributions of the northern Green Bay trout resembled those of the central Green Bay specimens in that few fish of large size were taken (none as large as 19 inches); however, the modes of the frequencies were identical with those of the northern Lake Michigan trout for two (2½, 2⅝) of the three meshes, and at the same interval as for fish from central Green Bay in the 2¾-inch mesh.

The length-frequency distributions show that relatively few lake trout, even where abundant in the area fished, were caught which were smaller than those within the range of maximum effectiveness of a given mesh size, whereas considerable numbers that were larger than these fish were captured. The capture of large individuals was undoubtedly more or less accidental and in some instances was the result of their attempts to feed on chubs or other small fish caught in the nets. Although there was no uniform increase in the size range of fish taken with each increase in mesh size, the 3-inch mesh showed the widest spread in lengths of lake trout taken. Fish caught in this mesh ranged in length from 7.6 to 34.7 inches. The latter fish, a 16-pound nearly ripe female caught off Sheboygan, Wis., on October 6, 1931, was the largest lake trout recorded during the three-year study. The smallest lake trout, 6.9 inches in length, was caught in a 2¾-inch-mesh net off Racine, Wis., at a depth of 34 fathoms on June 3, 1931.

CONDITION (*K*) AND LENGTH-WEIGHT RELATION

The coefficient of condition K was computed for each of 11,228 lake trout collected during the years 1930–32 from the relationship $K=\frac{W\times 10^5}{L^3}$ where W=weight in grams and L= standard length in millimeters. Data were tabulated originally according to port, month, year, length of fish, and mesh size, and were later combined where this action was justified.

The grand average coefficient of condition of lake trout from the various extensive collections of the lake proper (table 24) ranged from 1.20 in 1932 (upper Lake Michigan) to 1.34 in 1930 (lower Lake Michigan). The average for the Green Bay fish was 1.22 (table 25). These grand average values are not strictly comparable because they did not cover the same months of the year. May is the only month for which data were available for the three regions. The May averages were: lower lake, 1.29; upper lake, 1.20; Green Bay, 1.25. The other monthly values for the main lake (June–Sept.) also show that K was higher in the trout of lower Lake Michigan than in those of the upper lake. The monthly differences between the coefficients of the trout of the two regions were, however, of no greater magnitude, as a rule, than the discrepancy between the grand averages of 1930 and 1931 for the lower lake. The grand average K for all fish including those from Green Bay was 1.25 (table 27).

Table 24.—Average condition factors (K) of lake trout, grouped according to year and season of collection, for lower and upper Lake Michigan

[Number of fish shown in parentheses]

Month	Lower Lake Michigan		Upper Lake Michigan
	1930	1931	1932
May		1.29 (791)	1.20 (87)
June	1.28 (6)	1.26 (440)	1.22 (482)
July	1.36 (334)	1.27 (774)	1.20 (636)
August	1.37 (310)	1.32 (850)	1.19 (1,768)
September		1.31 (426)	1.25 (165)
October		1.25 (734)	
November	1.24 (133)	1.24 (625)	
Grand average	1.34 (783)	1.28 (4,640)	1.20 (3,138)

Seasonal changes in condition among lake trout collected in Lake Michigan proper in 1930–32 are shown in table 24; those for trout of Green Bay, 1932, are given in table 25 and are discussed later. The collection period on the main lake covered 7 months (May through November) in 1931, but was of shorter duration in 1930 and 1932. In the more extensive collections of 1931, the average K decreased slightly from 1.29 in May to 1.26 and 1.27 in June and July, increased to the seasonal highs of 1.32 and 1.31 in August and September, and decreased in October and November to 1.25 and 1.24, respectively.

Average values of K were markedly higher in July and August in 1930 than in 1931 for lake trout collected in lower Lake Michigan, although the seasonal changes were the same in direction in both years during the summer and late fall. The seasonal high (1.37) of 1930 occurred in August (as it did in 1931), and this value was nearly identical (1.36) in July. Coefficients of condition in November were the same (1.24) in the two years.

In northern Lake Michigan the lake trout had a lower average K (1.19 to 1.20) in May, July, and August, 1932, than in the other two months in which collections were made. Values were only slightly higher in June (1.22) and September (1.25), the latter being the seasonal high.

The seasonal changes in condition shown in table 24 were followed closely by fish taken in each mesh size, considered separately. The inclusion of data on lake trout collected in lower Lake Michigan in 1930 and 1931 in the 2⅜- and 3-inch-mesh nets (not used in northern Lake Michigan in 1932), therefore, had no significant effect on either the monthly or annual average K values (see e. g. table 26; average for 2½–2¾ was 1.27; for all meshes, 1.28). Comparisons between these values of the trout of the two regions are therefore valid.

The most marked change in condition observed over a relatively short period of time (possibly related to the resumption of a new season's growth) was among lake trout collected in central Green Bay early in 1932 (table 25). Within the 5½-week period during which collections were made in this area, the grand average coefficient of condition increased progressively from 1.19 (April 21–28) to 1.27 (May 19–28). The greatest increase occurred near the middle of this period. Fish of both sexes

Table 25.—Average condition factors (K) of male and female lake trout, grouped according to size of mesh and dates of collection in central Green Bay, 1932

[Number of fish shown in parentheses]

Dates of collection	Taken in mesh size (extension measure) of—									
	2⅜ inches		2½ inches		2⅝ inches		2¾ inches		2⅜-2¾ inches	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
April 21–28	1.19 (55)	1.17 (43)	1.17 (107)	1.18 (90)	1.19 (95)	1.19 (94)	1.21 (122)	1.22 (97)	1.19 (379)	1.19 (324)
April 29–May 6	1.21 (42)	1.19 (39)	1.20 (116)	1.21 (83)	1.21 (106)	1.18 (93)	1.22 (128)	1.20 (97)	1.21 (392)	1.20 (312)
May 11–18	1.24 (21)	1.26 (16)	1.26 (114)	1.25 (96)	1.24 (103)	1.24 (80)	1.24 (86)	1.23 (77)	1.25 (324)	1.24 (269)
May 19–28	1.30 (50)	1.29 (54)	1.25 (82)	1.26 (69)	1.27 (69)	1.25 (50)	1.24 (37)	1.26 (48)	1.26 (238)	1.27 (221)
April 21–May 28	1.23 (168)	1.23 (152)	1.22 (419)	1.22 (338)	1.22 (373)	1.21 (317)	1.22 (373)	1.22 (319)	1.22 (1,333)	1.22 (1,126)

caught in each mesh size were noticeably heavier during the period May 11–18 than during the interval April 29–May 6 (no nets lifted May 6–9).[1]

As a rule smaller differences were observed between K for the periods April 21–28 and April 29–May 6, and May 11–18 and May 19–28 than for the periods April 29–May 6 and May 11–18. The greatest increases in average K with the advance of the season were made by the lake trout caught in the 2⅜-inch mesh. The difference in K of the fish taken in the first and last of the four periods of collection decreased with each increase in mesh size (from about 0.12 to 0.03).

No consistent difference in K related to sex was observed in the large collections of lake trout made in the restricted central waters of Green Bay within the period April 21–May 28 (table 25). The average K for the entire collection was 1.22, and the same value was found for each sex. This similarity of condition factor for both sexes was also noted in 2,096 sexed lake trout collected off the ports of Manistique and Charlevoix (northern Lake Michigan) in 1932. The average K values were identical (1.20) for the 1,052 males and 1,044 females. On the basis of the collections from these ports and from Green Bay, it was assumed that there was no difference in K related to sex among any of the immature lake trout in Lake Michigan. Data for other regions and years have, therefore, not been analyzed separately according to sex. Seasonal differences in K related to maturation of the sex products would not be expected (and were not observed) since nearly all of the lake trout of the collections covering the 3-year span of 1930–32 were sexually immature (p. 78).

Lake trout from the extensive collections of lower Lake Michigan

[1] This difference is accentuated if data for 207 lake trout (sex undetermined; average K 1.28) taken from nets lifted May 10 are combined with the May 11–18 data. The marked increase in condition between the May 11–18 and April 29–May 6 specimens was accompanied by a decrease in the average length of fish caught in each mesh size. The grand average length (all meshes combined) of fish caught April 29–May 6 was 13.1 inches; for May 11–18 it was 12.8 inches.

Table 26.—Average condition factors (K) of lake trout, grouped according to length of fish and size of mesh in gill nets, for lower Lake Michigan, 1931

[Number of fish shown in parentheses]

Total length (inches)	Taken in mesh size (extension measure) of—					Average
	2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches	
5.0–6.9				1.41 (1)		1.41 (1)
10.0–10.9	1.30 (43)	1.34 (7)	1.17 (2)	1.21 (5)	1.29 (2)	1.29 (59)
11.0–11.9	1.26 (270)	1.30 (121)	1.35 (45)	1.40 (16)	1.05 (1)	1.28 (453)
12.0–12.9	1.23 (234)	1.26 (381)	1.28 (326)	1.32 (150)	1.32 (19)	1.27 (1, 110)
13.0–13.9	1.24 (120)	1.24 (267)	1.26 (303)	1.28 (390)	1.36 (119)	1.27 (1, 199)
14.0–14.9	1.25 (33)	1.25 (100)	1.25 (183)	1.28 (240)	1.31 (297)	1.28 (853)
15.0–15.9	1.24 (19)	1.24 (29)	1.25 (70)	1.28 (131)	1.31 (260)	1.29 (509)
16.0–16.9	1.29 (14)	1.31 (21)	1.29 (30)	1.30 (44)	1.29 (121)	1.29 (230)
17.0–17.9	1.27 (2)	1.28 (8)	1.29 (10)	1.27 (24)	1.30 (54)	1.29 (98)
18.0–18.9	1.33 (3)	1.43 (4)	1.20 (2)	1.29 (15)	1.33 (24)	1.32 (48)
19.0–19.9	1.14 (2)	1.34 (2)	1.35 (1)	1.31 (8)	1.41 (15)	1.35 (28)
20.0–20.9	1.21 (1)		1.60 (1)	1.43 (2)	1.41 (4)	1.41 (8)
21.0–21.9	1.45 (2)	1.39 (6)		1.33 (3)	1.51 (3)	1.41 (14)
22.0–22.9	1.39 (1)	1.48 (1)		1.51 (3)	1.35 (7)	1.40 (12)
23.0–23.9			1.27 (1)	1.68 (1)	1.44 (2)	1.46 (4)
24.0–24.9				1.30 (1)	1.37 (2)	1.35 (3)
25.0–25.9	1.65 (1)			1.57 (3)	1.35 (2)	1.51 (6)
26.0–26.9				1.38 (1)	1.40 (1)	1.39 (2)
29.0–29.9			1.29 (1)		1.47 (1)	1.38 (2)
34.0–34.9					1.65 (1)	1.65 (1)
Grand average	1.25 (745)	1.26 (947)	1.27 (975)	1.29 (1, 038)	1.32 (935)	1.28 (4, 640)

in 1931 showed a progressive increase in the grand average K with each increase in mesh size, from 1.25 in the 2⅜-inch mesh to 1.32 in the 3-inch mesh (table 26). The tabulation according to mesh size and length of fish indicates that this would be expected as there was a trend within each length class (among the better represented size classes, 11.0–15.9 inches) toward an increase in K with each increase in mesh size. For example, in the 12-inch class K ranged progressively upward from 1.23 in the 2⅜-inch mesh to 1.32 in the 2¾- and 3-inch meshes; in the 13-inch length group the range extended from 1.24 in the 2⅜- and 2½-inch meshes to 1.36 in the 3-inch mesh. However, after the trout reached 16 inches and more in length their coefficients did not change consistently in one direction with the increase in mesh size. For example, in the 16-inch length class the average values of K remained nearly constant (1.29–1.31) for the fish taken in the five meshes. The fluctuations in the averages among the larger trout were no doubt largely the result of

the paucity of specimens. The data suggest that the coefficient of condition (robustness) was not an important factor influencing the capture of these larger fish in the small-mesh gill nets employed in this study.

Contributing also toward the higher coefficient of condition in the larger mesh sizes (which of course took the larger fish) was the general trend toward an increase in K with increase in fish length. This trend, which would be expected in view of the length-weight relation (p. 53), is clearly revealed when the data for all meshes are combined. They show that K tended to increase with increasing length (except for slight decreases from 1.29 in the 10-inch class to 1.27 in the 12- and 13-inch classes). The average K of lake trout of various lengths was as follows: less than 15 inches, 1.27; 15.0–17.9 inches, 1.29; 18.0–19.9 inches, 1.33; 20.0–26.9 inches, 1.42 (see also table 27 for all trout).

Near the mode of the length-frequency distribution of fish collected in each mesh size (where gill-net selectivity would be expected to exert its greatest effect) the trend was toward a decreasing coefficient of condition with increasing fish length. In other words, a given gill-net mesh took the more robust smaller fish and the leaner longer fish within the size range where body girth was the primary factor determining the escape or capture of fish. In the 2⅝-inch mesh, for example, K values ranged from 1.35 in the 11-inch class downward to 1.25 in the 14-inch class; in the 3-inch mesh the range was from 1.36 in the 13-inch class to 1.29 in the 16-inch class. With two exceptions (in the 2¾- and 3-inch meshes), average K values decreased progressively from the length class preceding the modal group downward through the length class following the modal group in the length-frequency distribution. Gill-net selection apparently was a less important factor of condition among fish of lengths farther removed from the modes of the length-frequency distribution of the respective meshes. At first the K values of the length classes following the modes remained almost constant in each mesh but among the trout 16 inches (18 in the 3-inch mesh) and more in length the averages again increased, reaching values as high or higher than those at the modal lengths. These higher averages fluctuated considerably because of the small numbers of fish involved, although there was a tendency for them to rise in the larger individuals.

Similar trends of an increase in K with an enlargement in mesh size for fish of the same length group and of a decrease in K with an increase in length of fish taken in the same size of mesh were observed also in the collections of lake trout from the lower lake in 1930, Green Bay (1932),[2] and northern Lake Michigan (1932) when tabulated separately. The data re-emphasize the need for the exercise of caution in the use of length-weight data

[2] This trend of increasing K with increasing mesh size was clearly evident in the Green Bay lake trout, when tabulated by length class and mesh, but was not shown by the data as presented in table 25 (except to a limited extent in the collections of April 21–28). The distribution of the variations in K and numbers of fish was such that this trend was concealed when data for the full season of collection were combined.

from gill-net samples, as pointed out by Deason and Hile (1947). They found a relationship between size of mesh and condition in the Kiyi similar to that shown here for small lake trout.

No consistent relationship between age of small lake trout and condition was demonstrable in a sample of 274 fish collected in upper Lake Michigan in 1932. Condition factors of these fish were tabulated by age groups (III–V), 1-inch length intervals (range, 12.0–15.9), and mesh size (2½–2¾ inches). Although the data suggested an increase in the average coefficient of condition with an increase in age between groups IV and V, the difference was small; it was not observed between fish of age groups III and IV, the average K values of which fluctuated at random. The numbers of fish in each category of length, age, and mesh size, although larger than those available in other homogeneous samples which might have been selected, were undoubtedly too small to give a reliable indication of the relationship between age and condition.

Data on the length-weight relationship of lake trout from Lake Michigan (including Green Bay) are summarized in table 27. These figures of the fish from all meshes and of both sexes were combined for the various regions, years, and seasons of capture. Although certain regional and/or annual and seasonal differences were observed (table 24) and, as indicated above, gill-net selection was a factor in determining the robustness of the fish collected, the general length-weight relationship can be expressed more satisfactorily by a single curve (fig. 15) than by separate curves for the different major collections. The curve was fitted to the average weights and lengths of fish grouped by ½-inch intervals of length between the extremes of 9.5 and 22.9 inches. Within this range, each length group was represented by four or more fish. The equation for the curve is:

$$\text{Log } W = -5.4652 + 3.1377 \text{ Log } L,$$

or

$$W = 0.3426 + 10^{-5} L^{3.1377},$$

where W = weight in grams and L = total length in millimeters. The weight of Lake Michigan lake trout within this length range thus increased as the 3.1377 power of the length.

Agreement between empirical and calculated weights (table 27, fig. 15) is only approximate along portions of the curve. Empirical weights were larger than the computed weights for all trout under 12.5 inches in length with one exception, the fish of the 9.0–9.4-inch length interval (specimens under 9.5 inches were not used to construct the curve). Empirical weights were less than computed weights of lake trout between the lengths of 12.4 and 19.5 inches (with the single exception of fish in the 18.5–18.9-inch interval) and were more than the computed weights for fish between the lengths of 19.4 and 23.0 inches (with the exception of fish in the 20.5–20.9-inch group). The average absolute deviation for all classes upon which the curve was based was 22 grams (0.8 ounce). In the poorly represented length classes ranging (with several interruptions) from 23.0 inches to 34.9

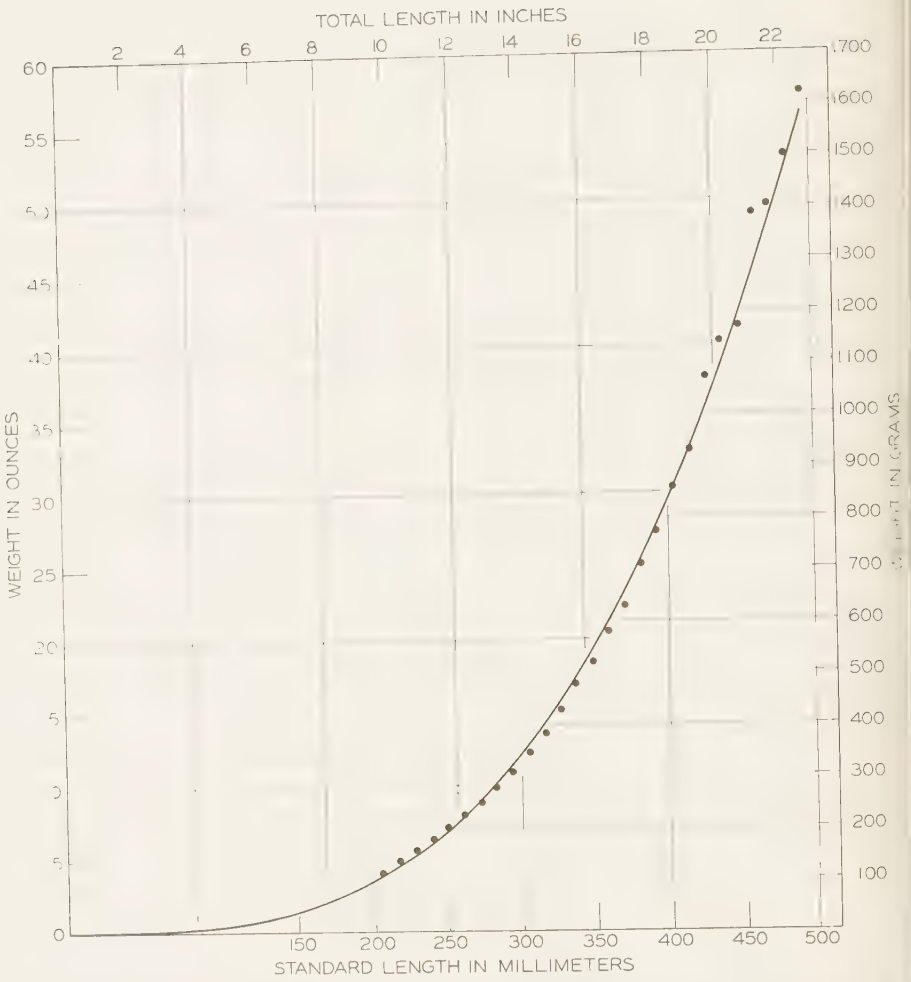

Figure 15.—Computed length-weight relationship of lake trout from Lake Michigan (including Green Bay), 1930–32. The dots represent the empirical data as given in table 27.

inches (not used in computation of the curve) the empirical weights were again more than the computed with three exceptions (the intervals 24.0–24.4, 27.0–27.4, and 29.0–29.4).

The deviation of the empirical data from a simple curve based on computed values is apparently inherent in the data (perhaps due to gill-net selection) and is not the result of combining material from the different regions and years of collection. Separate length-weight curves prepared for lower Lake Michigan (1930–31), upper Lake Michigan (1932), and Green Bay (1932) showed the same type of inflection in the length-weight relation that was observed when all data were combined.

Table 27.—Length-weight relationship and condition *K* of Lake Michigan lake trout, 1930–32

Total length (inches)	Average weight		Computed weight (grams)	Number of fish	*K*
	Ounces	Grams			
-6.9					
-7.4	1. 50	43	34	1	1. 41
-7.9					
-8.4	2. 00	57	52	1	1. 18
-8.9	2. 50	71	64	3	1. 21
-9.4					
-9.9	3. 13	89	92	2	
)–10.4	3. 94	112	109	4	1. 15
5–10.9	4. 83	137	128	33	
)–11.4	5. 57	158	149	174	1. 28
5–11.9	6. 29	178	173	369	
)–12.4	7. 08	201	197	822	1. 28
5–12.9	7. 97	226	225	1, 201	
)–13.4	8. 81	250	256	1, 429	1. 25
5–13.9	9. 85	279	287	1, 640	
)–14.4	10. 88	308	323	1, 546	1. 23
5–14.9	12. 21	346	363	1, 197	
)–15.4	13. 53	384	405	806	1. 23
5–15.9	15. 14	429	447	599	
)–16.4	16. 88	479	496	470	1. 26
5–16.9	18. 37	521	549	255	
)–17.4	20. 42	579	601	226	1. 26
5–17.9	22. 20	629	660	139	
)–18.4	25. 03	710	724	75	1. 27
5–18.9	27. 19	771	786	70	
)–19.4	30. 27	858	858	28	1. 29
5–19.9	32. 82	930	934	25	
)–20.4	37. 83	1, 072	1, 014	24	1. 33
5–20.9	40. 20	1, 140	1, 092	10	
)–21.4	41. 28	1, 170	1, 181	8	1. 35
5–21.9	48. 85	1, 385	1, 275	13	
)–22.4	49. 47	1, 402	1, 366	15	1. 39
5–22.9	52. 86	1, 499	1, 470	7	
)–23.4	57. 17	1, 621	1, 579	9	1. 38
5–23.9	71. 50	2, 027	1, 693	2	
0–24.4	68. 75	1, 949	1, 804	3	1. 48
5–24.9	63. 83	1, 810	1, 919	3	
0–25.4	79. 83	2, 263	2, 060	3	1. 37
5–25.9	87. 62	2, 484	2, 186	6	1. 51
0–26.4					
5–26.9	96. 25	2, 729	2, 477	3	1. 42
0–27.4					
5–27.9	90. 50	2, 566	2, 780	1	1. 26
0–28.4					
0–29.4	112. 00	3, 175	3, 108	1	1. 43
5–29.9	110. 00	3, 119	3, 476	1	
5–30.9	142. 25	4, 033	3, 656	1	1. 38
5–34.9	153. 00	4, 338	4, 066	2	1. 45
	257. 75	7, 307	5, 959	1	1. 65
All lengths				11, 228	1. 25

STANDARD LENGTH–TOTAL LENGTH RELATION

Factors for converting standard S. L.) to total lengths (T. L.), and ice versa, of the lake trout of Lake Michigan are shown in table 28. n order to determine whether the out of the entire lake may be eated as a unit, the data of the ears 1931 (lower lake) and 1932 pper lake) were analyzed separately. An interesting trend was ound in the differences between ne average $\frac{\text{S. L.}}{\text{T. L.}}$ ratios of the comparable length intervals (see footnote to table 28). In fish within the range of 144–307 millimeters, standard length, the 1932 values were consistently the higher (average 0.006) with three exceptions (1 less, 2 the same). Then, within the range of 308–382 millimeters the two series approached each other (slightly less, the same, or slightly more) with the 1932 average slightly lower (−0.001). Thereafter (range 383–422), with two ex-

ceptions (+0.004 and +0.006), all 1932 values were the smaller (average difference −0.003). In other words, lake trout under 14.3 inches, total length, had relatively shorter tails (higher $\frac{S.\ L.}{T.\ L.}$ ratios) in northern Lake Michigan (1932) than in the lower part of the lake (1931), but the reverse was true for the fish larger than 17.9 inches. The trout between these sizes had tails of about equal relative length. The differences between the two groups of the two regions of the lake, although they are not significant in the application of the ratios as length conversion factors, may be an expression of a racial characteristic (the existence of different populations or races in the two areas of Lake Michigan has long been suspected). Since the differences between the 1931 and 1932 $\frac{S.\ L.}{T.\ L.}$ ratios were small and the breaks or shifts in the two series occurred at nearly the same points the data for both years have been combined in table 28.

In order to employ larger numbers of trout more than 422 millimeters, standard length, specimens from Lake Huron were also utilized after it was determined that no consistent differences existed between these and the Lake Michigan fish. Comparisons were made of the average $\frac{S.L.}{T.L.}$ ratios of fish for each 5 millimeters standard-length interval and within a size range of 373–522 millimeters. The average difference was only 0.003, the Lake Huron trout having the higher value.

The combined data of table 28 show that there is a gradual and progressive change in the conversion factors with increase in the length of the fish, although the difference between each succeeding average is not large.

Table 28.—Factors for converting standard to total length and vice versa of lake trout from the Great Lakes

[Trout of 423 millimeters, standard length, and larger were from Lakes Michigan and Huron; all others were from Lake Michigan taken in 1931 and 1932]

Standard-length interval (millimeters)	Number of fish	Standard length to total length [1]	Total length to standard length [1]
144–242	539	1.200	0.834
243–342	9,644	1.186	.844
343–447	1,149	1.181	.847
448–487	125	1.175	.851
488–597	86	1.168	.856
598–776	28	1.160	.862

[1] The factors are unweighted values based on the weighted averages of each 5 millimeter (S. L.) interval of fish 223 to 492 millimeters long. Larger intervals were employed for the smaller and larger trout, the range depending on the numbers of available specimens. Factors for converting S. L. (millimeters) to T. L. (inches) and T. L. (inches) to S. L. (millimeters) may be obtained respectively by dividing the values of column three by 25.4 and by multiplying those of column four by 25.4.

Many factors can influence the variability of our data of abundance of lake trout collected by the experimental gear off the different ports and in the various regions of the lake. Among them are depth of water, season and year of collection, age and size composition of the catch, size of mesh of the gill nets, and the length of time the nets fished before being lifted. In such a large body of water as Lake Michigan (about 307 miles long, 118 miles wide, and 923 feet deep) with its scattered breeding grounds and diverse environmental conditions and fishery activities, we may expect to find real local differences in the abundance of lake trout. Because the variability of the above-mentioned factors may lead us to erroneous conclusions, it is essential that extreme caution be exercised in analyzing our data. We have attempted to isolate each factor but found that in certain instances such a breakdown reduced the quantity of data to a point where no positive conclusions could be made from them. We were then forced to rely in part on our judgment based on an overall view of all of the data.

Variation with size of mesh (selectivity)

Table 29 shows the average number and pounds of lake trout taken per gill net of each size mesh in different sections of Lake Michigan in 1930–32. In each area and in the same year or years, equal or nearly equal numbers of nets (fourth column) were employed for each mesh, and all fished at the same time and places. The averages of each row are therefore strictly comparable for the different meshes.

Our experience has shown that in order to obtain highly trustworthy figures on the selectivity

Table 29.—Average number and pounds of lake trout caught per gill net of each mesh size in Lake Michigan, 1930–32

Area and year	Total number of nets	Number of nets of each mesh	Average catch per net with mesh size of —									
			2⅜ inches		2½ inches		2⅝ inches		2¾ inches		3 inches	
			Number	Lbs.	Number	Lbs.	Number	Lbs.	Number	Lbs.	Number	Lbs.
East shore,[1] 1930–31	674	[2] 135	6.6	3.8	9.5	6.3	10.2	7.6	9.8	8.5	8.6	9.1
West shore,[1] 1930–31	1, 180	236	3.5	1.9	3.6	2.4	3.5	2.5	3.5	3.2	3.1	3.7
Lower Lake Michigan:[4]												
1930	321	[3] 64	5.1	2.7	5.8	3.9	5.4	4.1	5.7	5.3	5.2	5.6
1931	1, 533	[4] 307	4.5	2.5	5.7	3.8	6.1	4.4	5.9	5.1	5.1	5.7
1930–31	1, 854	[5] 371	4.6	2.6	5.8	3.8	6.0	4.4	5.8	5.1	5.1	5.7
Lake Michigan,[6] 1930–32	1, 620	[7] 405	5.2	2.8	6.0	3.8	6.0	4.3	5.8	5.0	--	--
Upper Lake Michigan,[8] 1932	1, 629	543	------	------	3.5	2.3	3.7	2.6	3.4	2.8	------	------
Lake Michigan,[9] 1930–32	2, 741	[10] 914	------	------	4.4	2.9	4.5	3.3	4.4	3.7	------	------

[1] South of Frankfort-Algoma line.
[2] 136 nets of 2⅜-inch mesh, 134 of 2¾-inch and 3-inch.
[3] 65 nets of 2⅜-inch mesh.
306 nets of 2¾-inch and 3-inch mesh.
[5] 372 nets of 2⅜-inch mesh, 370 of 2¾-inch and 3-inch.
[4] Lower Lake Michigan and central Green Bay for 1932.
[7] 406 nets of 2⅜-inch mesh, 404 of 2¾-inch.
[6] Includes northern and central Green Bay for 1932. Combined figures adequately represented selectivity for three areas even though abundance varied greatly (see table 38).
[8] All of Lake Michigan and Green Bay.
[10] 913 nets of 2¾-inch mesh.

of gill nets, it is necessary to use large numbers of nets, especially when the quantity of fish caught per net is small. We have, therefore, combined wherever possible the comparable data from all ports and areas of the lake and bay. This combination has enabled us to use 913 or 914 nets of each of the three intermediate-sized meshes, some 370 to 372 nets of each of the five meshes, and 404 to 406 nets of each of the four smallest meshes. To construct table 29 we employed 16,254 lake trout weighing 12,293 pounds taken in 3,517 gill nets. The data were also segregated for each year and for the main regions of the lake primarily to show that the conclusions derived from the combined figures were essentially the same as those reached for each year and area separately.

It is clear from the averages at the bottom of table 29 that no significant differences existed in the selectivity of the gill nets with meshes of 2½, 2⅝, and 2¾ inches so far as number of lake trout is concerned. The average catch per net was practically the same for all meshes (4.4, 4.5, and 4.4 fish). This conclusion also applies fairly well to the various sections of the lake, including upper Lake Michigan, and to the collections of the different years, when the number of nets of each mesh is taken into consideration.

The study of nets of all five meshes (2⅜–3 inches) was confined to lower Lake Michigan. The 1930–31 averages for these waters show that the catch per net was smaller in the 2⅜-inch- and 3-inch-mesh nets (4.6 and 5.1 fish) than in those with the three intermediate sizes of mesh (5.8, 6.0, and 5.8 fish). These differences have been explained by a shift in age composition (see p. 32). The smallest mesh nets caught 17.0 percent of the total number (10,134) of trout taken in lower Lake Michigan; the largest mesh nets took 18.7 percent; and the nets with the three intermediate sizes of mesh took from 21.2 to 21.8 percent (average 21.4). The differences between the average for the three meshes and that of the 2⅜-inch-mesh nets (4.4 percent) and the 3-inch-mesh nets (2.7 percent) do not appear from a practical standpoint to be significantly large.

The reduced catch in the smallest mesh used in the lower lake was mainly the result of the relatively low availability of the trout to these nets along the east shore in both 1930 and 1931. (The combined 1930–31 figures of table 29 accurately depict the true situation of each year for both coasts.) In these waters the 2⅜-inch-mesh nets caught fewer trout than the average for the three intermediate meshes in 80 percent of the gangs lifted in 1931 and in 66 percent of those lifted in 1930. Apparently the smaller sizes of trout were relatively less abundant, as compared with the larger fish, along the east shore than off the west.

The percentage of decrease in the 3-inch-mesh nets was nearly the same for both shores (12 and 11). Inasmuch as the trout caught in the 3-inch meshes were older and larger (tables 11 and 22) than those taken in the smaller meshes, their reduced catches may be expected from the normal cumulative effects of natural and fishing mortalities with increased age and size of the fish.

The 1930–32 Lake Michigan averages that covered the lower lake and central Green Bay also showed the smallest catch (5.2 fish) in the 2½-inch-mesh nets (only three other sizes of mesh were used with the 2½-inch in the central bay), although the discrepancy here was not so marked as for the lower lake. This reduced difference resulted from the relatively large take in the 2½-inch-mesh nets in central Green Bay. Here these nets (34 of each kind; total 126) took the greatest number of trout (11.6 as compared with 8.1, 6.4, and 5.5 in the three larger meshes; corresponding pounds were 4.8, 4.0, 3.6, 3.6) as a result of the 1932 spring run of small fish that were heavily dominated by age group III (see table 11 and p. 70).

It may be concluded that in general all of the gill nets, irrespective of which of the five different meshes was employed, were just about equally destructive to small lake trout; there was no large variation in catch with the size of mesh in the net represented collections; a shift from one mesh to another within the range of sizes used would in the spring run have, for all practical purposes, little effect on the number of trout taken by gill nets employed in catching chubs.

With respect to the number of pounds of lake trout taken by the various nets of different meshes, we have a different situation. We find that for all years and areas (the spring run of central Green Bay excepted; see above) there was always a progressive increase in the number of pounds taken per net with each increase in the size of the mesh. This increase in number of pounds, in contrast to the relative constancy in the number of fish, is the result of the progressive increase in the average weight of the individual trout with each increase in the size of mesh. As shown in table 22 the average weight of the lower Lake Michigan trout taken in nets with meshes of 2⅜, 2½, 2⅝, 2¾, and 3 inches was 8.8, 10.5, 11.8, 14.0, and 17.8 ounces, respectively.

It should be pointed out here that with respect to the destruction of small trout, reference should be made to the numbers of individuals rather than to their total bulk-weight or to their percentage in the entire catch of chub-net lifts. Van Oosten (1933) stressed this point because of the confusion that existed in the thinking of the commercial fishermen. His pertinent comments, which are still valid, are quoted here because they are now quite inaccessible.

> The data have been given in terms of "numbers per net" rather than percentages, since percentages do not express the actual abundance of the fish per net but only the relative abundance. In speaking of the amount of destruction of lake trout in the various sized meshes, the fishermen nearly always refer to the percentage of trout in the catch, either by number or by weight. Sometimes reference is made to the total number of pounds of trout. These methods have been the underlying cause of the disagreements and confusion among the commercial fishermen concerning the question of the destructiveness of the various sized meshes to baby trout.
>
> Let me illustrate the fallacy of using percentages in this case, by referring to the data on the number of trout and chubs taken in the 2⅝″ and 2¾″ mesh nets fished in lower Lake Michigan off the Michigan shore (see first row of data

in table). [Table omitted here.] The table shows that the 2⅝″ mesh nets took on the average 9.4 trout plus 66 chubs or a total of 75.4 fish. Expressed in percentages these nets took 12 percent trout and 88 percent chubs. The 2¾″ mesh nets took on the average 9.4 trout plus 43 chubs or a total of 52.4 fish. Trout comprised 18 percent of this total, chubs 82 percent. Thus it is seen that while the 2⅝″ mesh nets took 12 percent trout by number in Michigan waters, the 2¾″ mesh nets took 18 percent, an increase of 6 percent. If we follow the same procedure as above for the corresponding figures of weight, shown in the lower half of the table, we find that the 2⅝″ mesh nets took 24 percent trout by weight, while the 2¾″ mesh nets took 39 percent, an increase of 15 percent. On the basis of these percentages we would conclude that in the Michigan waters of Lake Michigan the 2¾″ mesh gillnets are more destructive to baby lake trout than the 2⅝″ mesh nets. But, are they? Do these 2¾″ mesh nets destroy more individuals than the 2⅝″? Referring again to the first row of data in the table, we see that the 2⅝″ mesh nets destroyed 9.4 baby trout and that the 2¾″ mesh nets destroyed exactly the same number. Hence these two sizes of mesh were equally destructive to baby trout in Michigan waters and the differences in the percentages shown above are entirely due to the decrease in the number and weight of chubs taken in the 2¾″ mesh nets. It is, no doubt, clear now that any discussion of the destructiveness of chub-nets to lake trout must be based on the number of individuals destroyed and not on the percentages or total weights.

Variation with number of nights out

It is common knowledge among the commercial fishermen that on the whole there is a direct relationship between the size of a lift of fish from gill nets and the length of time the nets fished. It has been found, for example, that the commercial catch of whitefish in large-mesh gill nets increased progressively with each increase in t number of nights that the n fished during a period of five nig (Van Oosten, Hile, and Job 1946). Similarly the lifts of ch from commercial gill nets w found to increase with each ad tional night's fishing until the ter night when the catch started a p gressive decline. The number nights ranged from four to elev (Van Oosten 1935). These Gr Lakes whitefish and chub catc were, of course, recorded in poun and since they were obtained fr the reports of many commer fishermen the data for the differ nights out were not based on stric comparable materials.

It is of interest to learn what fluence the length of fishing t had on our abundance figures trout expressed in numbers. order to utilize strictly compara data the total catches were f segregated according to year, lo ity, size of mesh, depths of wa month or season of collection, number of nights out. The aver take per net was then calcula for the different number of nig out when more than one net involved. Next, the catches net of each year and locality w averaged for those pairs of nig out for which comparable data w available. These compara means were then consolidated all areas and years to obtain final grand average values. A a careful analysis it was decide employ only the grand aver catches of each two succee nights out as shown in table These averages of each row in body of the table are strictly c

30.—Grand average number of lake trout per net for different numbers of nights out

ges of each row in the body of the table are comparable with respect to localities, years, months, depths ater, and mesh sizes. Values at the bottom are all related to the catch of one night. See text for methods mputation. Number of nets involved is shown in parentheses]

For nights out numbering—														Percentage difference
2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1.0 (111)														100
1.0 (111)	0.7 (18)													−30
	0.2 (60)	0.8 (54)												300
		1.8 (108)	2.2 (213)											22
			4.4 (300)	5.6 (354)										27
				4.3 (264)	3.7 (213)									−14
					2.4 (214)	3.6 (91)								50
						7.5 (111)	7.4 (86)							−1
							3.8 (80)	3.6 (75)						−5
								5.5 (111)	3.6 (105)					−34
									4.2 (130)	4.9 (120)				17
										5.4 (95)	5.2 (140)			−4
											4.3 (105)	3.6 (70)		−16
												2.6 (20)	3.8 (20)	46
1.0	0.7	2.8	3.4	4.3	3.7	5.6	5.5	5.2	3.4	4.0	3.8	3.2	4.7	

ble with respect to the several ors mentioned above (as year, lity, and depth). The method omputation employed in this ection as well as in others on ation in abundance is intended void giving undue weight to ptionally large lifts of fish or numbers of lifts made at any time or in any one area or h interval or with a particular of mesh.

or each pair of the comparable d averages of table 30 we com- d the percentage of change with increase in the number of ts out (last column). With the of these percentages the catch net for the different nights out brought into direct relation with night's lift (0.5) by the following edure. The first average in bottom row was multiplied by the first percentage (100) in the last column, and the resultant value was added to the 0.5 to provide the mean catch (1.0) for two nights out; this average was then multiplied by the second percentage (−30) to obtain the mean take for the third night; the third night's lift (0.7) was multiplied by the third percentage (300) and increased to 2.8 for the fourth night's yield; and so on. The bottom row shows, then, the average number of trout taken per single net for the several fishing periods that ranged from 1 to 15 nights out. These figures, of course, do not represent the actual catch (except the first three); they are theoretical lifts based on a 1-night take of 0.5 trout. They do, however, represent in general the true trend in the change of the

catch with the increase in fishing time.

The data indicate that the catch per net did not consistently rise with each increase in the number of nights out. There was, however, an upward trend (declines occurred at the third and seventh night) through the eighth night from 0.5 fish to 5.6, an elevenfold increase. Thereafter the catch decreased progressively through the fourteenth night except for the pronounced drop at the eleventh night. However, only slight reductions occurred at the ninth and tenth night; the peak reached at the eighth night remained nearly constant (5.6, 5.5, 5.2) through the tenth. The take again showed a sharp rise at the fifteenth night, the maximum fishing time for which comparable data were available.

The records suggest that a saturation point was reached at the eighth night when no more trout could be taken in the chub nets. This apparent maximum concentration lasted three nights with only a slight progressive decline. Or we may assume that the loss of gilled trout from the nets was no longer compensated or exceeded by new captures after the eighth night. Losses exceeded gains (if the nets continued to take trout) through the fourteenth night when the average take dropped to the level of the fifth night's catch. In the fifteenth night the yield started to rise again reaching the approximate level of the sixth night's catch. Comparable figures based on lifts for other than succeeding nights suggest that the increase in catch of the fifteenth night was the beginning of another upward trend which would ha continued at least through t twentieth night. It is of interest note also that the apparent satur tion point for the lake trout end at almost the same time (nin night) as for the chubs in co mercial gill nets (p. 60).

Variation with year of collection

Strictly comparable materials f use in this subsection were availal only for the years 1930 and 19 To obtain such data the avera catch per net was computed f those trout that were caught in t same locality, month, depths water, and size of mesh. The means were then averaged for ea locality and size of mesh, and t resultant values combined for localities to obtain the grand av ages for the lake as shown in tab 31.

The data of this table reveal th in general more trout were taken p net from lower Lake Michigan 1931 than in 1930. The avera catch per net was 6.1 fish in 19 and 7.5 in 1931, an increase of percent. The average fishing ti involved in these yields did not va greatly in the two years (10.5 a 11.2 nights) and most probably w not a factor in the difference of t catch.

Although the take of all of t experimental nets, with the exc tion of that of the 2¾-inch-me nets, indicated a lesser abundan in 1930, there were pronounc shifts in the discrepancies betwe the lifts of the two years with change in mesh size. The diff ence increased progressively fr 0.6 to 3.7 fish with each larger me

ble 31.—Comparisons between number of lake trout taken per net of different mesh sizes in 1930 and 1931 in lower Lake Michigan

ta for each year were collected off the same ports and in corresponding months and depths of water. Number of nets involved in each average is shown in parentheses]

Year	Average number nights out	Average number taken per net with mesh size of—					All meshes
		2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches	
	10.5	6.1 (59)	8.4 (59)	9.3 (59)	7.2 (59)	6.3 (59)	7.5 (295)
	11.2	5.5 (29)	5.2 (28)	5.6 (28)	8.0 (28)	6.1 (28)	6.1 (141)
merical difference		0.6	3.2	3.7	−0.8	0.2	1.4
centage difference		11	62	66	11	3	23

the range from 2⅜ to 2⅝ inches, en dropped in reverse to −0.8 in e 2¾-inch-mesh nets and to 0.2 in e 3-inch-mesh nets.

The shifting trend in the differences suggests that the sizes of out most vulnerable to a particular mesh did not maintain in e nets with different sizes of esh the same ratio of abundance tween the two years. The length equencies of the fish collected in 30 and 1931 confirm this assumption.

The shift seems to be related to difference in the age composition the trout particularly the change the relative abundance of the o dominant age groups. As was inted out previously the III- id IV-year fish dominated the tch of the nets with meshes that nged from 2⅜ to 2¾ inches. he year in which the fish of these o groups were relatively most numerous (table 32) was also the year in which the average catch per net was the larger (table 31). The IV- and V-group trout formed the bulk of the catch of the 3-inch-mesh nets. The relative abundance of these fish was about the same (79 and 81 percent in both years); hence the difference in the catch per net also varied very little (0.2 fish or 3 percent).

It is to be noted that the largest discrepancies (62 and 66 percent) were recorded for the lifts from the nets with meshes of 2½ and 2⅝ inches in length. The differences among the fish caught in the other nets varied from 3 to 11 percent, which by comparison are small. The discrepancy between the average take of the two years based on the fish caught in all nets was then largely the result of the variations in yield from the 2½- and 2⅝-inch-mesh nets.

ble 32.—The 1930 and 1931 percentages of the trout of age groups III and IV combined in the catch of nets with meshes of 2⅜–2¾ inches and of IV and V combined in the catch of 3-inch-mesh nets

Year	Percentage in mesh size of—					Number of fish
	2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches	
31	93	82	85	66	79	151
30	76	75	71	72	81	63

The maximum discrepancy (3.7) occurred in the lifts from the 2⅝-inch meshes. Since age group IV reached its maximum vulnerability in these meshes (see table 23 for vulnerable lengths and p. 43 for average lengths of age groups) and strongly dominated the catch from them, it may be assumed that the difference in take of the two years was largely an expression of the difference in strength of the two year classes involved, 1926 and 1927, the latter being the stronger. The 4-year trout were somewhat less vulnerable to the 2½-inch meshes and the difference in the catch was slightly reduced to 3.2. As the bulk of the lifts from the other nets included more and more individuals of other age groups and length classes, the influence of the IV-group trout on the total take diminished and the discrepancies were reduced. With each decrease in the size of the mesh below 2⅝ inches more individuals of age group III and fewer of the older fish entered the catch, and with each increase above 2⅝ inches more fish of age groups V and VI and fewer younger trout were caught. The difference in the average catch of 1930 and 1931 seemed to have been primarily the result of a difference in the strength of the 1926 and 1927 year classes as represented by age group IV.

Variation with months

Tables 33, 34, 35, and 36 provide data on the variation in the average number of lake trout taken per net in different months. These values are not strictly weighted averages. They were obtained in the following manner. For each locality and yea the weighted average catch per ne was obtained for each month fo those trout that were taken a depths within the same 10-fathon range and with nets of the sam combination of meshes. For certai ports the data were kept separat for nets of different meshes (tabl 33). Comparisons for any tw months represent fish taken withi the same depth ranges whether fron shallow or deep water. To obtain summary for all localities and year combined the weighted means wer averaged for each month. The aver ages for the number of night out are, however, weighted value Comparisons in tables 33 to 36 ar therefore, strictly comparable wit respect to localities, years of colle tion, depths of water, and sizes c mesh. It was impossible to obtai sufficient data for comparisons tha also represented equal numbers c nights out. The average fishin times are shown in the tables. The indicate that in most instances th differences between the averag number of nights out were not larg There certainly was no correlatio here between these differences an the percentages of change in th number of trout.

Table 33 was compiled to demon strate that the conclusions wit respect to change in abundance be tween months would be the sam whether the means for each mes size or a general average for a nets were employed. The figure show that the direction of chang was always the same for all com parable averages and that no rela tion existed between the degree c variation and the size of mes

Table 33.—Variation in number of lake trout per net in different months

[Data for any two months compared are strictly comparable with respect to ports, year of collection, depths of water, and size of mesh. All trout were taken in 1931 from lower Lake Michigan]

Month	Total number nets	Average number nights out	Number per net with mesh size of—					All meshes	Percentage change in number trout
			2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches		
[illegible]	190	12.6	5.1	6.1	5.6	7.6	6.8	6.2	
[illegible]	260	12.1	4.2	5.2	5.4	4.5	4.4	4.7	−24
[illegible] Difference		−0.5	−0.9	−0.9	−0.2	−3.1	−2.4	−1.5	
[illegible]ember	110	11.3	3.1	4.7	4.5	4.5	3.7	4.1	
[illegible]ber	110	11.7	7.8	8.0	7.1	8.4	6.8	7.6	+85
[illegible] Difference		0.4	4.7	3.3	2.6	3.9	3.1	3.5	
[illegible]ber	105	10.8	3.9	3.7	3.4	3.8	3.0	3.6	
[illegible]ember	75	11.8	5.1	5.2	4.4	5.2	4.5	4.9	+36
[illegible] Difference		1.0	1.2	1.5	1.0	1.4	1.5	1.3	

Table 34.—Variation in number of lake trout per net in different months

[Data for any two months compared are strictly comparable with respect to ports, years of collection, depths of water, and sizes of mesh (2⅜ to 3 inches). All trout were taken from lower Lake Michigan except those caught off Charlevoix, Michigan, in June and July 1930 (20 nets)]

Month and year	Total number nets	Average number nights out	Number trout per net	Percentage change in number trout
[illegible]y 1931	190	12.6	6.2	
[illegible]e 1931	260	12.1	4.7	−24
[illegible]e 1930–31	191	11.6	5.9	
[illegible]y 1930–31	185	11.6	5.8	−2
[illegible]y 1930–31	255	12.2	5.6	
[illegible]ust 1930–31	275	10.6	6.9	+23
[illegible]ust 1931	275	9.5	10.2	
[illegible]tember 1931	180	11.3	7.2	−31
[illegible]tember 1931	110	11.3	4.1	
[illegible]ober 1931	110	11.7	7.6	+85
[illegible]ober 1931	105	10.8	3.6	
[illegible]vember 1931	75	11.8	4.9	+36

[illegible]cept that the difference was [illegible]ways smallest in the trout from [illegible]e 2⅝-inch-mesh nets.

The averages of table 34 were [illegible]sed on a combination of the data [illegible] all fish from nets with meshes [illegible]at ranged from 2⅜ to 3 inches in [illegible]ngth (lower Lake Michigan) and [illegible]e values of table 35 were founded [illegible]n all trout from nets with meshes [illegible]at varied from 2½ to 2¾ inches [illegible]pper Lake Michigan). The per-[illegible]ntage figures show that the abundance of trout decreased from April to May in 1932 in Green Bay. In both Green Bay and Lake Michigan proper the catch also declined from May to June. The June and July averages were practically the same. Abundance increased in August followed by a decline in September and rises in both October and November. The directions in percentage change were always the same where comparisons could be made for both upper and lower Lake

Table 35.—Variation in number of lake trout per net in different months

[Data for any two months compared are strictly comparable with respect to ports, year of collection, depths of water, and sizes of mesh (2½–2¾ inches). All trout were taken in 1932 from upper Lake Michigan]

Locality and month	Total number nets	Average number nights out	Number trout per net	Percentage change in number trout
Menominee, Mich.:				
April	87	4.7	8.4	
May	273	6.3	5.7	−32
Escanaba, Mich.:				
May	54	5.7	1.6	
June	63	11.3	1.2	−25
Northern Lake Michigan:				
July	306	6.2	3.0	
August	285	5.2	5.5	+83
August	201	5.1	2.7	
September	165	6.2	0.7	−74

Michigan waters. In the upper lake the largest catches were made in central Green Bay in April.

It is evident from these data that seasonal changes occurred in the abundance of small trout. In the lake as a whole, it declined from early spring to July, then remained constant, rose in August, decreased in September, and increased in October and again in November.

It is of interest to learn whether seasonal changes in the availability of lake trout were the same for both sides of the lower lake and for both shallow and deep water (50 fathoms was the approximate dividing line). Examination of the detailed figures revealed that with only four exceptions, two on each shore, the direction of the shift in the monthly average catch per net was the same for both depths of water. The values of table 36, therefore, represent all depths.

Seasonal availability of lake trout varied with the two shores of the lake. In the State of Michigan waters (east shore), the average catch decreased from May to June, showed practically no change in July, increased in August, declined in September, and rose pronouncedly in October. The west side averages agreed with those of the east shore only in the direction of the shifts from May to June and from September to October; in the other months from June to September, inclusive, the data disagreed. The seasonal changes of the east shore were in accord with those of the northern waters as well as of the lake as a whole, wherever they covered the same months; the west coast changes, of course, showed the same discrepancies here as in their comparisons with the east shore.

Reasons for the discrepancies in seasonal trends between the two sides of the lake are not clear. Variations with calendar years do not provide an adequate explanation although in our data differences did exist between the 1930 and 1931 data. Along the east shore the average catch decreased 14 percent from June to July in 1930 but increased 19 percent in 1931. Similarly the take decreased 9 percent from July to August in 1930 and increased 98 percent in 1931. Along the west coast the average

e 36.—Variation in number of lake trout per net in different months for east and west shores of lower Lake Michigan

for any two months compared are strictly comparable with respect to ports, years of collection, depths of water, and sizes of mesh]

Month	East shore					West shore				
	Year	Number of nets	Average number nights out	Number trout per net	Percentage change in number trout	Year	Number of nets	Average number nights out	Number trout per net	Percentage change in number trout
J	1931	90	12.0	6.5	−12	1931	100	13.4	6.0	−37
J	1931	70	12.0	5.7		1931	190	12.2	3.8	
	1930–31	96	10.7	6.7	+1	1931	95	12.4	3.1	−26
	1930–31	130	12.0	6.8		1931	55	10.7	2.3	
	1930–31	135	12.3	7.3	+41	1930–31	120	12.5	3.9	−10
t	1930–31	145	10.2	10.3		1930–31	130	11.5	3.5	
t	1931	85	9.1	17.0	−34	1931	190	9.6	2.2	+4
nber	1931	65	11.0	11.2		1931	115	11.4	2.3	
nber	1931	40	10.6	4.7	+126	1931	70	11.9	3.3	+15
er	1931	20	13.0	10.6		1931	90	11.2	3.8	

h also decreased (21 percent) n July to August in 1930 and eased (42 percent) in 1931. trend in August, then, was the e for both shores when each year considered separately, not when h years were treated as a unit. vever, discrepancies still per- ed between the data of the two sts for the months of July 19 and −26) and September 31 and +4) 1931.

Ve are fortunate in having on d some pertinent lake-trout istics copied by the senior hor at the time of the investiga- in 1930 from the books of a mercial fisherman at Two Riv- Wis. These records were based his daily catch of the number of nds of dressed lake trout taken chub nets during the period tember 1925–May 1930 (table It is of interest to compare results based on these records h those obtained from our erimental data. The size of h used in these commercial nets was 2½ inches, stretched measure, except for a brief period in late 1929 and early 1930 when some 2⅝-inch-mesh gill nets were also employed. We have no information on the depths in which the nets fished but the gangs of nets were of uniform length. Neither do we know the exact number of nights the nets were out between lifts, although it is known that the fishing time between lifts was as a rule also constant from year to year for the same fisherman.

The trout were separated by the fisherman into two groups according to marketing demands. The No. 2 fish varied from about ½ to 1 pound in dressed weight, and the No. 1 trout weighed about 1¼ pounds and larger. Very few fish weighed less than ½ pound. The larger fish were more or less accidental captures. They did not gill but were entangled usually by their teeth. This fact accounts for their irregular and wide fluctuation in the catch of the small-mesh gill

Table 37.—Monthly variation in pounds of dressed lake trout per lift taken by a commerc fisherman, September 1925–May 1930, at Two Rivers, Wis., and monthly fluctuation number of lake trout per net caught by experimental gear in upper and lower Lake Michig 1930–32

Month	Year	Number of lifts	Pounds of No. 2 trout per lift	Percentage change in pounds	Percentage change number	
					Upper Lake Michigan	Lowe Lak Michi
January	1926–30	87	112			
February	1926–30	84	95	−15		
March	1926–30	96	120	+26		
April	1926–30	96	259	+116		
May	1926–30	99	226	−13	−32	
June	1926–29	83	183	−19	−25	
July	1926–29	83	182	0		
August	1926–29	92	135	−26	+83	
September	1925–29	88	99	−27	−74	
October	1925–29	115	104	+5		
November	1925–29	99	122	+17		
December	1925–29	102	160	+31		
January	1926–30	87	112	−30		

nets. Because of this erratic variation in the production of the No. 1 trout (large or moderate lifts were made in 1925, 1926, and 1930; very few of these fish were taken in 1927, 1928, and 1929) and because our data involve almost wholly lake trout of small size, discussion of the fisherman's records will be confined to his No. 2 fish.

An examination of the average monthly catch per lift of each year showed that with a few scattered exceptions the direction of the change in abundance from month to month was remarkably constant with the years. The records of all years have, therefore, been combined for each month (table 37). As in our experimental nets, so also here the average catch per unit of effort fluctuated with the months. It decreased from January to February, increased each month through April, declined through June, remained constant in July, then continued to decrease through September, rose each month through December, and dropped in January.

These monthly fluctuations Two Rivers coincide very well w those of the lower and upper l despite the fact that the latter expressed in terms of number trout (table 37). The only imp tant discrepancy is the change fr July to August. Whereas the fi erman's data showed a decline 26 percent, our records revealed creases of 83 and 23 percent. T former did, however, agree with August trend of our 1930 (not 1931) data for both shores. In much as our figures covered entire lake and identical trends w obtained for the upper and lo sections, we should perhaps acc our results with respect to the puted month of August. The fi erman's statistics offer little aid solving the previously descri conflicts between the data of east and west shores. They s ported the results for the east sh with respect to the change in J and September but not that August.

ıation with areas in the lake
geographical distribution)

.e average number of trout
per net was compiled for
area or port by year, month,
depth of water (10-fathom in-
ls) and for the same combina-
of mesh sizes. To compare the
of two areas these weighted
ges, based on the number of
shown in table 38, were com-
l for those trout that were
in the same years and months,
in the same depths of water, and with the same sizes of mesh. However, weighted averages were employed for the cross sections of the lake. These data gave more consistent results than the unweighted averages. It was not possible to make the records strictly comparable with respect to the number of nights out. However, as shown in table 38, the average (weighted) fishing times for the comparable lifts did not vary greatly, and as

38.—Variation in average number of lake trout per net in different areas of Lake Michigan

or any two regions compared are strictly comparable with respect to years and months of capture, depths of water, and sizes of mesh employed. See fig. 2 for location of ports and points of capture]

Areas	Number of nets	Average number of nights out	Average number of trout per net	Percentage change in number of trout
ın:				
)–31 (mesh sizes 2⅜–3 inches):				
St. Joseph–South Haven	50	11.8	4.3	
Grand Haven–Muskegon	60	10.3	2.8	−35
St. Joseph–South Haven	40	12.8	4.1	
Ludington–Manistee	55	11.8	10.8	+163
Grand Haven–Muskegon	100	12.2	4.2	
Ludington–Manistee	90	11.8	10.8	+157
Ludington–Manistee	85	11.3	8.0	
Frankfort	55	10.5	10.6	+32
Frankfort	30	11.3	7.6	
Charlevoix	20	10.0	9.8	+29
2 (mesh sizes 2½–2¾ inches):				
Leland	105	4.8	3.3	
Charlevoix	102	5.1	6.4	+94
Manistique	366	6.0	3.4	
Charlevoix	312	6.2	5.0	+47
Escanaba	54	5.7	1.6	
Menominee	273	6.3	5.7	+256
-Wisconsin, 1930–31 (mesh sizes 2⅜–3 inches):				
Waukegan	85	10.3	4.8	
Milwaukee–Sheboygan	95	12.5	7.5	+56
Kenosha–Racine	70	12.0	4.3	
Milwaukee–Sheboygan	50	12.5	2.3	−46
Kenosha–Racine	85	10.7	3.0	
Two Rivers–Kewaunee	65	10.7	2.9	−3
Milwaukee–Sheboygan	70	12.6	2.6	
Two Rivers–Kewaunee	55	10.3	3.9	+50
ichigan, 1930–31 (mesh sizes 2⅜–3 inches):				
West shore	785	11.8	3.7	
East shore	435	11.6	10.2	+176
South section	185	11.3	5.8	
Central section	220	11.1	5.1	−12
South section	55	12.3	5.1	
North section	100	12.4	8.2	+61
Central section	541	11.6	3.6	
North section	285	11.4	6.8	+89

judged by the figures of table 30 could not have accounted for the differences in the average catches of the several regions in the lake. The percentages indicate the amount of increase or decrease in the catch.

The number of small trout per net varied with the areas of the lake. Along the east shore (State of Michigan) there was a definite trend in abundance from south to north. The comparisons show that the production was the lowest in the Grand Haven–St. Joseph areas, highest in the Charlevoix territory, and intermediate in the waters between these ports. There may be some question as to the reliability of the Charlevoix average which was based on only 20 nets lifted on June 26 and July 7, 1930. Later comparisons (p. 72) indicate that the trout were less abundant in the northern waters than along the east shore of the lower lake. It may be safer to state that the trout reached its greatest concentration along this eastern shore in the Frankfort area. The abundance in the areas off Manistique west of Beaver Island approached a level somewhere between that off Leland and Charlevoix and equaled about 68 percent of that of the Charlevoix fish. In Green Bay the central section produced more than 3½ times as many trout as the northern region.

The Green Bay situation is of special interest inasmuch as some commercial fishermen contended that spring runs of small trout never extended into the Green Island area, although testimony obtained by the senior author from the older fishermen at the time of the investigation indicated that such runs were of annual occu rence. Experimental nets were s in Green Bay to check this questio Nets with meshes of 2⅜, 2½, an 2⅝ inches were lifted during Se tember 21–October 4, 1930, fro depths of 10–20 fathoms in t vicinity of Chambers Island, Gre Island, and Peshtigo Shoal in t southern half of Green Bay. Ve few trout (173) were taken in t 180 nets that were fished in the fa The weighted average catch p net (data for all nets combine was only 0.8 in September a 1.3 in October.

In the spring of 1932 (Ap 21–June 13), nets with meshes 2⅜, 2½, 2⅝, and 2¾ inches we operated in the vicinity of Gre Island and with meshes of 2 2⅝, and 2¾ inches out of Escana on or near Whaleback Shoal, Cha bers Island, and Green Island (s map, fig. 2). All of these nets we set at depths that ranged from to 24 fathoms. There was a c cided difference in the abunda of the small trout in the differe areas of the bay. An avera catch per net of only 1.6 trout w obtained off Whaleback Shoal a north thereof, whereas south this Shoal to the Green Island are the mean was 7.1. The cor sponding average for the Gre Island region alone, utilizing ne with the same sizes of mesh, w 6.7 indicating that a spring r actually extended into the south waters.

This run later disappeared ev before the recent advent of the s lamprey. The reason for this d appearance is not known. Su sequent to 1932, the exotic sm

erus mordax) increased with
l strides in the Wisconsin
rs of Green Bay reaching a
ax in abundance in 1940 and
. Whether this event was a
r in reducing the trout popula-
is not known. A brief sur-
by a member of our Fish and
llife Service staff in 1943 con-
ed the report that the spring
had ceased. As was pointed
by Van Oosten (1947) certain
suggested a relationship also
een the abundance of smelt in
n Bay and the numbers of
herring (*Leucichthys artedi*),
whitefish (*Coregonus clupea-
is*), and perhaps walleyes (*Sti-
dion vitreum vitreum*) in those
rs.

ifferences in abundance existed
between areas off the west
e (Illinois–Wisconsin) of Lake
nigan although no progressive
ge occurred from south to
h. There was, however, a gen-
tendency for the number of
t to increase in the lifts in the
northerly waters. The lowest
uction was obtained in the
hernmost waters in Illinois and
second lowest in the central
s off Milwaukee–Sheboygan,
the record for the highest pro-
ion in the northern region off
Rivers–Kewaunee was matched
he catch off the southern ports
Kenosha–Racine. Except for
discrepancy the variation in
ndance was very similar along
shores of the lake even though
number of trout was 2.8 times
ter (176 percent increase) off
east than off the west coast
lower part of table 38).

To determine whether a combination of more data might bring out more clearly the geographical variation in abundance in lower Lake Michigan, we divided this part of the lake into three cross sections and computed the weighted average number of trout per net for each area employing as before only those data that were strictly comparable with respect to years, months, depths, and meshes. Our southern imaginary line was drawn across the lake from the Illinois-Wisconsin boundary through station 19 to the Michigan shore (see fig. 2). The central dividing line was run from a point between Port Washington and Sheboygan, Wis., through station K to the Michigan shore. Our northern line was projected from Algoma, Wis., to Frankfort, Mich. The sections are designated South, Central, and North in table 38 where the weighted averages are shown for each region. The average periods of fishing time were nearly identical for the areas that were compared.

The data again indicated that the greatest abundance of small trout occurred in the northerly waters. The take here was 1.6 times (61 percent increase) that of the southern section and 1.9 times (89 percent increase) that of the central. The central section, however, produced fewer young trout per net than did the southern area although the difference was not large (0.7 fish or 12 percent decrease).

We are unable to make strictly valid comparisons between the catch of upper and lower Lake Michigan inasmuch as the years of collection, fishing time, and the

bathymetric distribution of the trout of the two regions were not the same. However, we may perhaps obtain a fair idea of the relative abundance of the small trout of the three main regions of the lake by comparing the general averages of the catch per net based on collections made in the same months of 1931 and 1932 (June to September inclusive), with the same sizes of mesh (2½, 2⅝, 2¾ inches), and at the same range of depths (20–79 fathoms). On this basis, weighted averages of the catch per net were computed for each 10-fathom interval for each of the months and for each year. The 10-fathom weighted means were then averaged for the entire period for each region. The resulting 1931 mean for the west shore based on 342 nets was 2.8 and for the east coast based on 233 nets it was 13.8. The 1932 average computed for 1,152 nets lifted from the northern waters (exclusive of Green Bay) was 3.3. On the basis of these figures, trout were 1.2 times as abundant during June–September in the northern waters as along the west shore of the lower lake and 4.2 times as numerous along the east shore as in northern Lake Michigan.

The above estimates do not consider the time fished between lifts in each section of the lake. This is unnecessary for comparisons in eastern and western Lake Michigan as the average fishing time was 11.1 and 11.3 nights, respectively. The distribution or range of the fishing times was also nearly the same as evidenced by the almost equal theoretical catches per net (see below). The data for northern Lake Michigan, however, we based on collections from n fished for an average of o 6.2 nights between lifts. Con quently, the estimates of abunda in this area, compared to those lower Lake Michigan, are n strictly comparable.

The data of table 30 showing t relation between nights out a average catch may be employ to make an adjustment for t discrepancy. We tabulated each region the total number nets that were lifted in 1931 a 1932 at the various periods of ti (nights out) and then multipli each of these numbers by t theoretical catch per net shown the bottom of table 30. The su mation of these catches divided the total number of nets gave the mean theoretical catch per n for each region for correspondi meshes, months, and depths water. These averages were: for the east shore, 4.3 for the w shore, and 3.7 for the upper la Production at the average of 1 nights fishing time was, therefo 1.2 times that at the average 6.2 nights. The application of t correction to the mean catch northern Lake Michigan increa it from 3.3 to 4.0, the theoreti catch at 11.2 nights out.

The adjusted figures did n change the general result w respect to the relative abunda of small trout in the three regio They were 1.4 times as abund in the upper lake as along the w shore and 3.4 times as numero along the east shore as in north Lake Michigan during June–S tember in 20–79 fathoms. Duri

e months in 1931 the east-
e yield was 4.9 times as large
the west-shore catch. This
rence was much greater than
more general value of 2.8 (p.
that covered a longer period of
and more territory.

ation with depth (bathymetric distribution)

able 39 presents our data on the
ymetric distribution of the
ll lake trout in Lake Michigan.
se figures are combinations of
hted averages of the original
rds segregated by areas, years,
ths, sizes of mesh, and depth
water. They are, therefore,
tly comparable in these re-
ts. As shown in the table, the
rences between the average
ghted) number of nights out
e not large, and bore no relation
he percentage change in the
age catch per net. The depth
water to which the nets were
gned was determined by the
n of the depths at the ends of
gang. Examination of the
hted averages for each port
e lake proper (excluding Green
) revealed a remarkably similar
ymetric distribution within
of three regions, namely, the
shore below Frankfort, Mich.,
west shore below Kewaunee,
., and the waters north of the
kfort–Algoma line designated
as the northeast shore. Com-
ng the data for each of these
ons as was done in table 39
herefore, fully justified.

mall lake trout were widely dis-
uted in lower Lake Michigan
were taken there at all stations
depths fished. Ninety-five percent of the nets set during the 2-year period caught lake trout.

A study of the comparisons and the percentage change in number of trout (table 39) indicates that the greatest concentration of these small fish along the eastern shore from Frankfort, Mich., south to St. Joseph, Mich., occurred in depths of 40 to 59 fathoms (probably greater in 40–49 than in 50–59). The average number per net increased progressively from the depth interval of 20–29 fathoms to that of 40–49 fathoms. Although there is some conflict with respect to the trend of the catch in 50–59 fathoms, probably because of the small number of nets involved, the weight of the evidence obtained from the percentages that involve the depth intervals of 40–49 and 50–59 fathoms indicates a decline. The abundance at 60–69 fathoms was less than in any of the shallower waters, and continued to decline to its lowest concentration in 70–79 fathoms.

The west shore as defined here extends from Kewaunee, Wis., to Waukegan, Ill. The data are not so complete nor are the number of nets involved here so large for this coast as for the east side for corresponding depths, especially the shallower water. Nevertheless, taking these facts into consideration, when we compare the corresponding percentages of change in the number of trout per net for both shores we find the agreement quite good with respect to the direction of this change (only two discrepancies, +96 and −12; −19 and +2), although the differences between the values of the west shore were in

Table 39.—Variation in average number of lake trout per net at different depths

[Data compared are strictly comparable with respect to ports, years, months, and sizes of mesh]

Average number of trout per net at depth of—								Percent change in number of trout	Number of nets		Average number of nights o	
10–19 fathoms	20–29 fathoms	30–39 fathoms	40–49 fathoms	50–59 fathoms	60–69 fathoms	70–79 fathoms	80–89 fathoms		A [1]	B [1]	A [1]	B [1]
East shore (1930–31), mesh sizes 2⅜–3 inches												
	5.4	5.9						+9	40	30	11.4	12
	4.7		9.2					+96	10	25	11.0	11
	4.7			10.2				+117	60	70	11.0	12
	8.4				6.8			−19	45	90	10.8	11
		3.9	13.1					+236	40	65	11.4	10
		5.2		12.7				+144	40	65	12.8	13
		11.6			6.4			−45	50	90	12.0	11
		4.0				0.5		−88	10	20	10.0	12
			28.5	15.0				−47	15	15	10.5	11
			34.5		13.0			−62	15	30	10.0	11
			38.8			7.0		−82	10	15	8.5	9
				28.1	3.2			−89	10	5	13.0	14
				2.9		1.1		−62	10	15	11.5	10
					22.7	12.0		−47	25	5	10.0	8
West shore (1930–31), mesh sizes 2⅜–3 inches												
0.6		5.1						+750	5	10	1.0	
	3.4		3.0					−12	40	40	12.5	
	4.3				4.4			+2	15	5	12.3	
	4.4					4.0		−9	20	15	12.5	
		2.6	6.3					+142	20	40	9.3	
		2.5		5.2				+108	130	130	10.9	
		4.3			3.9			−9	20	25	12.5	
		0.3				0.1		−67	10	70	10.0	
		3.5					0.3	−91	55	90	10.7	
			8.8		2.3			−74	70	75	12.6	
			3.6			3.2		−11	45	50	11.2	
				8.9		2.8		−68	15	15	14.0	
					4.4	4.1		−7	5	10	10.0	
East and west shores (1930–31), mesh sizes 2⅜–3 inches												
0.6		5.1						[2] +750	5	10	1.0	
	5.4	5.9						[2] +9	40	30	11.4	
	4.0		6.1					+52	50	65	12.0	
	4.7			10.2				[2] +117	60	70	11.0	
	7.6				6.3			−17	60	95	11.2	
	4.4					4.0		[2] −9	20	15	12.5	
		3.5	10.8					+208	60	105	10.8	
		4.0		9.3				+132	170	195	11.6	
		9.6			5.7			−41	70	115	12.1	
		2.2				0.3		−86	20	90	10.0	
		3.5					0.3	[2] −91	55	90	10.7	
			28.5	15.0				[2] −47	15	15	10.5	
			16.2		5.3			−67	85	105	12.1	
			21.2			5.1		−76	55	65	10.4	
				28.1	3.2			[2] −89	10	5	13.0	
				4.9		1.7		−65	25	30	12.3	
					13.6	8.0		−41	30	15	10.0	
Northeast shore (1932), mesh sizes 2½–2¾ inches												
[3] 2.8	0.4							−86	21	42	14.0	1
	9.1	5.6						−38	30	123	8.0	
	9.1		7.6					−16	30	93	8.0	
	9.1			0.7				−92	30	108	8.0	
	9.1				0.4			−96	30	36	8.0	
		6.2	4.2					−32	237	174	6.5	
		4.7		0.5				−89	195	450	6.7	
		4.5			0.4			−91	141	75	7.1	
			5.0	0.7				−86	198	510	5.8	
			5.2		0.4			−92	129	75	5.8	
				0.5	0.4			−20	243	75	6.6	

[1] Column A pertains to the first of each pair of averages compared, column B to the second.
[2] These values pertain only to one shore of the lake, either east or west.
[3] Escanaba data for Green Bay.

ieral the smaller probably be-
ise of the relative paucity of
ut. Here again, despite certain
flicts (see comparisons with the
a for 20–29 fathoms), the great-
concentration of small lake trout
parently occurred at depths of
-59 fathoms with the peak abun-
ice probably at 40–49 fathoms.
60–69 fathoms the average catch
net decreased, at least below
t at depths of 30–49 fathoms,
l in general declined progres-
ely thereafter reaching its lowest
el at 80–89 fathoms.

Because the behavior of the data
both shores was very similar
y were combined to provide more
nplete records for that section of
lake lying south of a projected
extending from Frankfort,
ch., to Algoma, Wis. These
a comprise the third section of
le 39. The combined figures
t actually involved both coasts
ported, where they had common
plication, the conclusions reached
each shore separately. Concen-
tion was greater at 40–49 fath-
s than at 20–29 or 30–39 fath-
s; it was also greater at 50–59
homs than at 30–39. At 60–69
homs, abundance was less than
any depth interval between 19
l 60 fathoms and at 70–79 fath-
s it was lower than in any shal-
er water.

In the waters off the northeast
re (1932), the distribution of
all trout differed from that of the
re southerly areas (1930–31).
re, in the northern waters, the
a showed the greatest concen-
tion at 20–29 fathoms (no ade-
ate figures for shallower waters)
l then a progressive decline with
greater depths, the fish almost disappearing from the catch in 50–59 fathoms and deeper water. There is, however, some question concerning the representativeness of the 9.1 average for the depth interval of 20–29 fathoms. This value was based on only two lifts, the weighted means for which were far apart (17.4 and 0.8). The values for the greater depths are much more trustworthy. These figures indicate that the greatest abundance occurred at 30–39 fathoms and the second greatest at 40–49. In northern Green Bay the small trout were much more numerous in 10–19 fathoms than in 20–29 (first row of last section of table).

We have not been able to determine with absolute certainty from our data whether the bathymetric distribution of the small lake trout had shifted with the season. To obtain reliable information on this question it is essential that the several factors (port, year, mesh) that affected the abundance of the fish be kept constant. When we followed this procedure our experimental data were too few to show conclusive results.

However, if we ignore the several factors that influence abundance and combine all of our data by depth and month we may obtain at least a good clue as to the probability of the existence of a seasonal trend in the bathymetric distribution of the small lake trout. The consolidated figures are shown in table 40. Examination of these averages indicates that no seasonal trend in bathymetric distribution occurred along the east shore; concentration persisted at depths of

Table 40.—Average number of lake trout taken per 510-foot gill net in lower Lake Michigan, arranged according to depth and month of capture

[1930 and 1931 data combined. Number of nets shown in parentheses]

Depth	Average number captured during—						
	May	June	July	August	September	October	November
East shore:							
20–29 fathoms	1.1 (10)	5.0 (5)	5.2 (40)	7.5 (60)	7.0 (5)		
30–39 fathoms	2.5 (30)	4.7 (36)	8.3 (30)	12.6 (5)	6.6 (18)	7.5 (25)	
40–49 fathoms	16.5 (15)	8.1 (15)	17.3 (20)	44.8 (5)	32.8 (5)	10.2 (20)	
50–59 fathoms	15.1 (15)	4.9 (10)	13.3 (40)	12.6 (25)	11.1 (20)	3.8 (5)	
60–69 fathoms		6.6 (20)	[1] 6.7 (45)	[2] 8.2 (50)	5.5 (15)	13.2 (5)	
70–79 fathoms	0.5 (20)			12.0 (5)	2.0 (10)	0.2 (5)	
West shore:							
10–19 fathoms							
20–29 fathoms	3.7 (10)	3.0 (30)	4.3 (15)	4.4 (5)			
30–39 fathoms	2.7 (20)	3.5 (30)	2.4 (40)	2.6 (85)	1.8 (50)	4.6 (50)	
40–49 fathoms	10.9 (30)	5.6 (65)	2.3 (35)	3.8 (25)		2.6 (30)	
50–59 fathoms	8.1 (20)	2.8 (30)	3.5 (20)	4.6 (30)	7.2 (30)	5.3 (45)	
60–69 fathoms	2.9 (20)	2.9 (35)	2.7 (35)	2.9 (20)			
70–79 fathoms			4.1 (10)	0.4 (75)	0.1 (15)	1.3 (30)	
80–89 fathoms				0.1 (30)	0.5 (20)	0.4 (25)	
90–99 fathoms						0.4 (15)	

[1] One atypical lift (15 nets) on steep bank, with nets extending from 35 to 101 fathoms not included.
[2] Two atypical lifts (total of 25 nets) on steep bank (25–101 fathoms) not included.

40–49 fathoms in all months from May to September, inclusive. The exception in October involving one lift was probably more or less accidental. Off the west shore a similar situation existed except that in May and June the greatest numbers were caught at 40–49 fathoms, and in the other months through November the fish seemed to prefer depths of 50–59 fathoms. Apparently along neither shore was there an appreciable mass movement of the small trout from one depth to anotner during the period May–November. It may be pointed out here that the distribution pattern based on the combined data is very similar to the one revealed by the more critical records of table 39, and this fact gives us some con dence in the use of the combin figures to study the seasonal patte of distribution.

The bathymetric distribution well as the actual abundance (tal 38) suggest that the small trout the east and west shores did n cross the lake over the deep basi (unless they swam above the foot gill nets). The populatio along each coast and in the nort ern waters apparently were more less distinct entities. If these sm fish mingled at all, they undoub edly did so by migrating mo or less parallel to the shoreline Tagging (Smith and Van Oost 1940) and marking (Van Oost 1950) experiments confirm t

v. They indicated that small trout did not move extensively ughout Lake Michigan until had reached adult size, and definitely followed the shore- in less than 55 fathoms in the hern waters to reach Green and the Wisconsin waters from Charlevoix, Mich., area where had been marked and released. ne of these Charlevoix fish have n known to cross the lake over p water.

n concluding this section on the ndance of trout it may be observed that many factors had to be considered in reaching final conclusions. The average catch per net, the basis employed by us in studying abundance, was influenced by many variables including the size of mesh used in the gill nets, length of fishing time (nights out) between lifts, calendar year and month of collection, and the localities and depths of water where the fish were taken. The abundance also varied with year classes, age composition, and the dominance of different age groups.

SEX RATIO

he numbers of males and fe- es among 13,529 lake trout which sex was determined in 0–32 are summarized in table 41 monthly intervals for various ions of Lake Michigan. The a for the east and west shores the lower lake are combined each of the years 1930 and 1931 n netting was restricted largely these regions, but the 1932 rds for central Green Bay and per Lake Michigan are given arately.

Males predominated in the catch small lake trout when data for various years and regions are bined, comprising 53.4 percent the total number of fish sexed. predominance of males was also ed in all designated sections of lake except northern Lake chigan in 1932, where slightly er males than females were ob- ved (49.5 and 50.5 percent, pectively). A second deviation m the grand average (not re- led in table 41) occurred along the west shore of the lower lake in 1930 where 483 fish scattered among six ports were again about equally divided between the sexes (241 males; 242 females). On the east shore, in contrast, 53.8 percent of the 732 fish examined were males. In 1931 sex ratios among the trout of the east (4,151 fish) and west (3,095 fish) shores were in much closer agreement, the males comprising 55.4 and 54.0 percent, respectively, of the totals sexed.

No consistent seasonal changes in sex ratio are shown by the data of table 41. In lower Lake Michigan in 1930, males were better represented in the July and August collections than in those made in November. However, the number of fish taken during the last month was probably too small to provide a reliable index. In this section of the lake in 1931, when large numbers of specimens were sexed, the sex ratio fluctuated without definite pattern from May through November, the percentage of males

Table 41.—Number and percentage of males and females in lake-trout collections in differer months from three regions of Lake Michigan, 1930–32

Month	Lower Lake Michigan								Upper Lake Michigan, 1932				Central Green Bay, 1932			
	1930				1931											
	Males		Females		Males		Females		Males		Females		Males		Femal	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	
April													447	53.9	382	4
May					662	56.1	517	43.9	27	40.3	40	59.7	886	54.4	744	4
June					578	51.2	552	48.8	188	46.5	216	53.5				
July	374	55.0	306	45.0	743	58.5	527	41.5	245	50.6	239	49.4				
August	213	50.2	211	49.8	823	51.1	788	48.9	754	50.2	748	49.8				
September					497	55.6	397	44.4	77	50.7	75	49.3				
October					412	59.6	279	40.4								
November	48	43.2	63	56.8	255	54.1	216	45.9								
April–November	635	52.3	580	47.7	3,970	54.8	3,276	45.2	1,291	49.5	1,318	50.5	1,333	54.2	1,126	

ranging from 51.1 to 59.6. In northern Lake Michigan in 1932, the percentage of males taken during the summer months was greater than that of the males caught in May and June, but the significance of part of these records is again questioned because of the relatively small numbers of fish collected in May and September and the apparent absence of similar seasonal changes among the trout of other areas. Marked changes in sex ratio during the spawning season (usually October), such as occurs commonly among various species of fish, was not expected since virtually all of our lake trout (98.7 percent of the males and 99.2 percent of the females) were sexually immature.

The sex ratio of small lake trout caught in central Green Bay coincided more closely with that of the specimens from lower Lake Michigan than with the ratio of the upper-lake fish (see April–June values, table 41). Part, if not all, of the discrepancies between the trout of upper Lake Michigan and those of the other two areas ma have been related to the differenc in the sizes of mesh employed an the sizes and ages of the trout tha were caught in these areas.

In our lake-trout data, ge selection could be a factor in th observed variations of the se ratio. In the lower lake five siz (2⅜–3 inches) of mesh were fishe at all times; in the upper lake thre sizes (2½–2¾ inches) were used 1932; and in central Green Ba 1932, three sizes (2½–2¾ inche were employed most of the tim and four (2⅜–2¾ inches) part the time. To learn whether ge selection was actually a factor, th sex ratios of the trout were d termined for each year and sever sections of the lake according t mesh size (table 42).

No progressive change in se ratio with change in mesh size wa found for any section of the lak However, with two exceptions (th west shore of lower Lake Michiga in 1930 and central Green Bay i 1932), the percentages of the mal

le 42.—Percentage of male lake trout in collections from gill nets of different mesh sizes, Lake Michigan, 1930–32

[Total number of males and females shown in parentheses]

Region and year	In mesh of—					Average
	2⅜ inches	2½ inches	2⅝ inches	2¾ inches	3 inches	
r Lake Michigan, 1930:						
ast shore	60.4 (106)	51.1 (139)	54.9 (144)	49.7 (187)	55.8 (156)	53.8 (732)
'est shore	51.9 (108)	49.1 (106)	57.3 (96)	42.0 (88)	48.2 (85)	49.9 (483)
Total	56.1 (214)	50.2 (245)	55.8 (240)	47.3 (275)	53.1 (241)	52.3 (1, 215)
r Lake Michigan, 1931:						
ast shore	55.8 (568)	58.3 (870)	54.0 (973)	53.3 (922)	56.1 (818)	55.4 (4, 151)
'est shore	55.3 (633)	53.3 (644)	53.6 (612)	53.5 (641)	54.3 (565)	54.0 (3, 095)
Total	55.8 (1, 221)	56.1 (1, 510)	53.6 (1, 589)	53.5 (1, 571)	55.3 (1, 386)	54.8 (7, 277)
al Green Bay, 1932	52.5 (320)	55.4 (757)	54.1 (690)	53.9 (692)		54.2 (2, 459)
r Lake Michigan, 1932		52.1 (858)	46.6 (962)	50.2 (789)		49.5 (2, 609)

en in the 2⅜-inch and 3-inch hes (not employed in northern e Michigan) were higher (com- ed average=54.5, 1930; 55.5, 1) than the average for the dle three meshes (combined rage=50.9, 1930; 54.4, 1931). discrepancies (3.6 and 1.1) e relatively small (particularly he large collection of 1931) when pared with those (2.8, 5.3, 4.7) ween the grand average values able 41 for upper Lake Michigan the other two areas. They e insufficient to explain entirely described differences in sex os of the trout in the various ers. Even though comparisons restricted to trout taken in gill s with identical mesh sizes (2½, and 2¾ inches) the percentages he males still remained greater the lower (50.9 and 54.4) than the upper (49.5) areas, although discrepances did decrease.

f we compare the averages for various regions for each mesh (2½, 2⅝, 2¾ inches) separately then it is observed that the values for the northern waters are not consistently the lowest as they were in table 41. The 1930 percentages of the lower-lake males were less than the percentages of the northern males for two of the three comparable meshes. It was the uncommonly and inexplicably low average (46.6) of the large number of males taken in the 2⅝-inch-mesh nets that reduced the grand average percentage for the northern waters. The percentages for the other nets operated in the north were not much out of line (grand average difference about 3.2) with those for the corresponding nets used in the lower regions and Green Bay. This statement is especially true when the discrepancies are compared with those that existed between the various lower-lake averages of the same year, but different sections (grand average difference about 3.0), or of the same sections but different

years (grand average difference about 5.2), or between the extreme averages of the randomly fluctuating monthly percentages in 1931 (8.5). It is our belief that the variations in sex ratios of the trout of the different areas of the lake were not biologically significant.

Another possible factor that might have influenced the variability of sex ratios in collections from upper and lower Lake Michigan and Green Bay is the larger size of lake trout caught in the northern waters (tables 22 and 23), combined with a general trend toward a decreasing percentage of males with increasing fish length (table 43). Inasmuch as the size of mesh affects the average length (and age) of the trout caught in gill nets, it is essential that only those fish be compared for the different regions that were taken in nets with the same combination of mesh sizes. Therefore, the data of table 43 were obtained only from trout that were captured in gill nets with meshes of 2½, 2⅝, and 2¾ inches in length. Individuals of extreme lengths, both small and large, were ignored in constructing the table because of their scarcity. The data show for each section of the lake and for each year the percentage of males in each 1-inch interval of total length.

A definite relationship existed between the lengths of the trout and sex ratio. Although the percentages of males fluctuated differently with increasing length in each region, they all showed a tendency to decrease. This trend is best revealed in the grand averages (last column). They decreased consistently with each 1-inch increase in the length of the fish, except in two length classes (15.0–15.9 and 17.0–17.9) where the percentages remained practically unchanged from the preceding intervals. The decrease continued until a sex ratio of 1:1 was reached by the trout in the two size groups between 13.9 and 1

Table 43.—Percentages of male lake trout from gill nets with meshes of 2½, 2⅝, and 2¾ inches grouped for each section of Lake Michigan and year by 1-inch intervals of length

[Total number of males and females shown in parentheses]

Total length (inches)	Lower Lake Michigan				Upper Lake Michigan 1932	Central Green Bay 1932	Grand average
	East shore 1930	West shore 1930	East shore 1931	West shore 1931			
10.0–10.9	80.0 (5)	0 (1)	75.0 (8)	60.0 (15)	75.0 (4)	65.6 (32)	66. (6
11.0–11.9	55.3 (38)	64.5 (31)	66.5 (176)	55.5 (182)	61.1 (54)	60.7 (285)	60. (7
12.0–12.9	49.6 (133)	45.0 (80)	56.1 (788)	55.1 (550)	55.5 (436)	55.9 (706)	55 (2,6
13.0–13.9	57.7 (163)	52.6 (78)	54.2 (914)	53.4 (577)	49.4 (834)	51.5 (732)	52 (3,2
14.0–14.9	48.5 (68)	48.9 (45)	52.4 (494)	51.7 (298)	46.4 (610)	53.8 (275)	50 (1,7
15.0–15.9	40.6 (32)	47.4 (19)	53.0 (215)	55.7 (149)	51.4 (360)	35.4 (48)	51 (8
16.0–16.9	57.1 (14)	33.3 (12)	60.0 (95)	37.5 (56)	42.8 (159)	50.0 (24)	47 (3
17.0–17.9	33.3 (6)	33.3 (3)	54.8 (31)	45.2 (31)	41.6 (77)	81.8 (11)	47 (1
18.0–18.9	0 (4)	0 (3)	31.6 (19)	50.0 (12)	61.8 (34)	60.0 (5)	46 (
19.0–19.9	50.0 (2)		28.6 (7)	66.7 (9)	16.7 (12)	100.0 (1)	38 (

es. Thereafter, the females dominant.

may be pointed out here that averages of table 43 based on mably adequate numbers of mens confirm our belief that no ficant differences occurred be- n the sex ratios of fish from the nern waters and the other ns of the lake. Comparisons e percentages of the males of ame length interval reveal that in the sizes of 10 to 16 inches sex ratios of the upper Lake igan trout did not differ greatly those of the other areas. The entage of the males at the th interval of 14.0–14.9 inches unusually low (46.4). This low age of one large length class ther with the greater numbers rge fish with low percentages the northern trout a smaller d average percentage.

e regional difference in size position was related to age position. As stated on page 45 variations in the sizes of the t in the three areas of the lake associated with the average The Green Bay collections strongly dominated by the group fish, the IV-year-olds ing second in importance; the age age was 3.32 years (p. 45). The lower-lake specimens were dominated by age group IV, the III-year fish occupying second place; the average age was 3.96 years. The collections from the upper lake, although also dominated by the IV-year trout followed in abundance by age group III, contained V-year fish in greater proportions (14 to 18 percent; table 14) than those of the lower-lake samples (8 to 11 percent; table 14); the average age was 4.23 years. All of the average ages and percentages are given for fish that were caught in the same combination of mesh sizes (2½, 2⅝, 2¾ inches).

We do not know whether the relative proportion of the males in the catch decreased in the older age groups. However, inasmuch as the lengths increased with age and the percentage of males decreased among the larger fish, it must follow that the relative number of males declined with increased age. Since the growth rates of the trout did not vary significantly with the areas (p. 38), the differences in lengths were the results of variations in age composition. Age was, therefore, basically the controlling factor in lowering the percentage of males in the collections from the northern waters of the lake.

ASSOCIATES OF YOUNG LAKE TROUT (SPECIES COMPOSITION)

The two years of netting in lower Lake Michigan (1930–31) emphasized the simplicity and uniformity of the fish fauna in the deeper waters (below 20 fathoms) of the large main basins of the lake. The collections comprising 123,227 fish included 109,755 chubs (89 percent), 10,134 lake trout (8 percent), 3,323 burbots (3 percent) and only 15 other fish distributed among five species.[3] Chubs, lake trout, and burbots occurred together at 87 of 88 stations fished and in 226 of a total of 234 separate net lifts during the period.

The catch of 39,238 fish in northern Lake Michigan (exclusive of Green Bay) was only slightly more varied, containing greater numbers of the shallow-water species which included 585 lake whitefish, 143 round whitefish, and 26 shallow-water ciscoes (lake herring). However, these three species together composed only 2 percent of the catch. The rest of the take consisted of 32,358 chubs (82 percent), 3,122 lake trout (8 percent), and 3,004 burbots (8 percent).

The species composition of the catch in northern Green Bay in the spring of 1932, where the nets were set at an average depth of only 19 fathoms, was intermediate in some respects between that in the shallower waters of central Green Ba and that in the deeper waters northern Lake Michigan. Six va eties of fishes were taken in northe Lake Michigan, 9 in northern Gre Bay, and 14 in central Green Ba The northern-bay percentages the common species in Green B (ciscoes and chubs) were intermec ate between those of the other tv regions. Chubs constituted 59 pe cent of the catch in northern Gre Bay, ciscoes 16 percent, lake whit fish 12 percent, lake trout 9 percer perch and smelt together 2 percer and round whitefish 1 percer Only two longnose suckers (*Catost mus catostomus*) were collecte Burbots were also scarce being re resented by only 10 individua among the 1,729 fish caught.

The large numbers of small la trout taken in central Green Bay the spring of 1932 shared the habitat with a number of speci not usually associated with ther and they were not accompanied l appreciable numbers of chubs an burbots, their most common a sociates in the main body of th lake. Lake trout and ciscoes eac composed about 37 percent of th 7,161 fish caught in central Gre Bay during the spring. Smelt mac up 10 percent and yellow perch percent of the take. Lake whitefis added 1 percent and carp (*Cyprin carpio*) about one-half of one pe cent. Central Green Bay, whe the nets were set at an averag depth of 16 fathoms, is probabl one of the very few localities i the Great Lakes where lake trou

[3] Three members of the family Cottidae, *Cottus cognatus gracilis*, *Cottus ricei*, and *Triglopsis thompsonii*, occasionally found entangled in gill nets by commercial fishermen, are also widely distributed in the main basin of Lake Michigan (Deason 1939). Of these only *Triglopsis thompsonii* was included among the 15 other fish. It was represented by three individuals. Others were yellow perch (*Perca flavescens*) (4), round whitefish (*Prosopium cylindraceum quadrilaterale*) (4), lake whitefish (3), and trout-perch (*Percopsis omiscomaycus*) (1).

nd carp have been taken simultaneously in gill nets. Occasional longnose suckers and white suckers (*Catostomus commersoni*) were collected, as well as saugers (*Stizostedion canadense*), round whitefish, and trout-perch. Chubs made up 7 percent of the catch and burbots were represented by 11 individuals. The species composition of the catch in central Green Bay in the fall of 1930 varied considerably from that of the spring of 1932. The ciscoes and chubs were much better represented in the autumn than in the spring, and the lake trout and smelt almost disappeared from the fall catch. Ciscoes supplied 75 percent of the 1930 take, chubs 17 percent, yellow perch 5 percent, lake trout 2 percent, and smelt 0.7 percent. Seven suckers were caught in addition to two burbots, two lake whitefish, one trout-perch, and one northern pike (*Esox lucius*).

SUMMARY

1. Experimental gill-net fishing for chubs and lake trout was conducted on Lake Michigan in 1930–32. Five sizes of mesh were employed: 2⅜, 2½, 2⅝, 2¾, 3 inches, stretched measure. This report covers only the data collected on the trout, including such items as size, growth, condition (*K*), length-weight and standard length-total length relationships, abundance, geographical and bathymetric distributions, sex ratio, and associates. Also discussed are techniques of estimating age and growth.

2. Total lengths instead of standard lengths may be employed in computing growth from scales.

3. Computed measurements of growth based on the diameters gave higher values than those based on the radii of scales; the former were therefore preferred for the study of growth.

4. Averages of computed growth for a group of fishes may be derived from calculations based on the average scale-diameter measurements of the entire group instead of from the scale measurements of each individual fish as has been done in the past. The latter method should be used when checking a doubtful age determination.

5. Scales of 212 presumably fin-clipped and recaptured lake trout from Lake Michigan were read and a maximum discrepancy of 20 percent was found between the known and estimated ages. It is certain, however, that all of the fish received with missing or deformed fins were not fin-clipped individuals released from the hatchery.

6. The fin-clipped trout provided information on the time of formation of an annulus or resumption of growth in the new growing season. About one-fourth of these fish had resumed growth by the end of the first week in July, about 50 percent by the middle of this month, some 80 percent by August 4, and 100 percent after August 25. No correlation was found between the time of resumption of growth and the ages of these fish.

The data of the wild trout indicated (*a*) that by June 15, 1932, all of the III-group trout, 28 percent of the IV-, 25 percent of the V-,

and 8 percent of the VI-group trout had resumed growth, and (*b*) that all trout caught on July 30 and later in 1932 and nearly all taken after August in 1930 or October in 1931 (the earliest collections in those years) had also renewed growth. Marked variations occurred in the time of resumption of growth with the different calendar years and age groups.

7. Among the wild trout marked differences existed in the length of the growing season not only between age groups but also between calendar years and localities. In 1930–31 only about half of the individuals had completed their growth in November.

8. Age groups III, IV, and V contributed the bulk of the catch from the main lake. Group III dominated the lifts from the 2⅜-inch-mesh nets, group IV dominated those from the nets with meshes of 2½, 2⅝, and 2¾ inches, and group V those from the 3-inch-mesh nets. The IV-year trout were the most abundant in the main lake. Age group V was better represented in the catch from the upper than from the lower lake; the reverse was true for the III-group. In central Green Bay age group III dominated the lifts from nets with meshes of 2⅜, 2½, and 2⅝ inches and group IV those from the 2¾-inch-mesh nets.

9. A detailed study was made of several variables (mesh, ports, calendar year of capture, year class, age) that might have influenced the increments of growth based on scales. The size of the mesh in the gill nets affected the total lengths at capture but not to a significant degree the calculated total lengt or increments of growth. N consistently significant differenc were found between the grow rates in different calendar years of five year classes or of tro taken from the different localiti or regions of the lake includi Green Bay. A progressive decrea in the average calculated inc ments occurred with an increase the age of the trout during the fi two years of life. In the thi year the decline still persist between the III- and IV-year fi but not between the older a groups or in the fourth year of li The presence of Lee's "phenomen of apparent change in growth rat was indicated in the increments growth.

10. Lake trout reached the f lowing average total lengths inches at the end of each complet year of life during the first 7 yea 3.4, 7.1, 11.7, 13.0, 14.4, 16.8, 18 Annual increments of growth tained from these values are: 3 3.7, 4.6, 1.3, 1.4, 2.4, and inches. Near the end of the four fifth, and sixth summer these f averaged, respectively, 8.9, 1(and 16.1 ounces in weight.

11. The average length a weight of the trout increased w each enlargement of the me In lower Lake Michigan wh all five meshes were used th averages ranged from 12.4 inc and 8.8 ounces for fish taken in 2⅜-inch-mesh nets to 15.2 inc and 17.8 ounces for those cau in the 3-inch-mesh nets. T progressive increase was the re not only of the selective action the meshes but also of the shift

e age composition of the fish. he average sizes of the lower- ke trout taken in the same size mesh did not vary significantly ther with the years of capture 930, 1931) or regions of the lake ast and west shore). The fish the upper lake consistently eraged larger in length than those ught in corresponding meshes ong the two shores of the lower ke, whereas the trout of central reen Bay always averaged smaller an the fish in the lake proper. The length-frequency distribu- ons show that relatively few lake out, even where abundant in e area fished, were caught which ere smaller than those within the nge of maximum effectiveness of given mesh size, whereas con- derable numbers that were larger an these fish were taken. The tter were accidental captures. he smallest trout taken measured 9 inches in length, the largest .7 inches.

12. The average coefficient of ndition (K) of 11,228 lake trout om Lake Michigan was 1.25, th a range of 1.20 to 1.34 among e various extensive collections different regions or years. The ghest monthly average K values curred within the period July to ptember. The most marked ange in condition over a short riod of time was observed among h collected in central Green Bay April–May 1932, whose average efficient ranged from 1.19 (April -28) to 1.27 (May 19–28). The coefficient of condition did t vary with sex; it tended to rease progressively with mesh e (particularly for fish of the same length class) and to increase with increasing length of the fish. However, near the mode of the length-frequency distribution of fish taken in each size of mesh, where gill-net selectivity would be expected to exert its greatest effect, the trend was toward a decreasing K with increasing fish length.

An analysis of the length-weight relationship indicated that between the extremes of 9.5 and 22.9 inches in length, the weight of Lake Michigan lake trout increased as the 3.1377 power of the length.

13. Factors for converting standard to total lengths and vice versa changed gradually and progressively with an increase in the length of the fish.

14. No significant differences were found in the average number of trout taken per net, the basis of all comparisons of abundance, in those gill nets with meshes of 2½, 2⅝, and 2¾ inches in length. The catch per net was smaller in the 2⅜- (except in central Green Bay) and 3-inch-mesh nets. In central Green Bay the 2⅜-inch-mesh nets took the greatest number of fish per net (no 3-inch meshes were used here) as the result of a large spring run of small trout that were heavily dominated by individuals of age group III.

The reduction in catch in the smallest and largest meshes and the relative constancy of the catch in the three intermediate sizes of mesh were related to the age composition of the fish. The percentages of the three dominant age groups (III, IV, V) in the total catch of the nets with the three intermediate sizes of mesh differed

very little. All three meshes drew upon the same stocks or groups of fishes. The reduction in average take of the nets with the other meshes resulted from a shift in dominance from the largest age group in the lake (IV) to the smaller groups (III, V).

15. The average number of pounds of trout per net increased progressively with each increase in the size of the mesh as the result of a corresponding progressive increase in the average weight of the individual trout.

16. The average number of trout per net increased elevenfold during the first eight nights of fishing, then declined during the next five nights, and rose again during the fifteenth night.

17. In 1930, the average catch per net was 6.1 trout and in 1931 it was 7.5, an increase of 23 percent. This discrepancy was largely the result of a difference in the abundance of the predominating IV-year fish (year classes 1926 and 1927).

18. The average catch per net declined from early spring to July, then remained constant, rose in August, decreased in September, and increased in October and again in November.

19. The number of small trout per net varied with the areas in the lake. Along the east shore of the lower lake there was a progressive increase in abundance from south to north, the greatest concentration occurring in the Frankfort area. Along the west shore there was a tendency for the fish to increase from south to north but no progressive change was observed since the concentration off the southern ports of Kenosh Racine was nearly the same as th in the Two Rivers–Kewaunee ar in the north. Trout were 2.8 tim as abundant along the east as the west shore. The concentrati in the Manistique fishing wat approached a level somewhere b tween that off Leland and Char voix. Central Green Bay produc more than 3½ times as many tro as the northern part of the ba Upper Lake Michigan produc fewer trout per unit of effort th the eastern waters of the lower la but greater yields than the weste It was estimated that the tro were about 1.4 times as abunda in the upper lake as along the we coast and 3.4 times as numero along the east coast as in the upp lake during June–September.

20. Young lake trout were wid distributed in lower Lake Michig and were taken here at all static and depths fished. The great concentration along both shores curred at depths of 40–59 fatho with the peak abundance probab at 40–49 fathoms. The lowest le always occurred at the great depths fished: 70–79 fathoms in t eastern and 80–89 fathoms in t western waters. In the waters the northeast shore (upper lake) t bathymetric distribution differ from that of the lower lake. Pe abundance occurred at 30–39 fa oms in the northern waters and t fish almost disappeared from t catch in 50–59 fathoms and deep waters. In northern Green B the trout were much more abunda in 10–19 fathoms than in 20–29.

No seasonal trend in bathymet distribution was observed amo

trout along the east shore dur- the period May–September. the west shore a similar situa- n existed except that in May and ne the greatest numbers were ught in 40–49 fathoms and in the ier months through November 50–59 fathoms. Apparently re was no appreciable mass vement from one depth to an- ier during the period May–No- nber. Neither did there seem have been such a movement from shore to another over deep ter. The populations of the ee major regions of the main e were more or less distinct ities.

1. Males comprised 53.4 per- t of 13,529 lake trout for which was determined. They exceeded ales in number in all sections the lake except northern Lake chigan (1932), where slightly er males than females were ob- ved. This difference was re- d to the larger size of lake trout caught in this region, combined with a general trend toward a decreasing percentage of males with increasing size and age. The sex ratio showed no consistent changes related to the season of the year or to the mesh size of the nets in which the fish were captured.

22. Chubs, lake trout, and burbots predominated in the gill-net catches in the main basins of Lake Michigan. Of 123,227 fish collected in 1930–31, chubs comprised 89 percent, lake trout 8 percent, and burbots 3 percent. The 1932 collection of 39,238 fish in upper Lake Michigan was composed of 82 percent chubs, 8 percent lake trout, 8 percent burbots, and 2 percent other species. The catch in Green Bay in the spring of 1932 was more varied in species composition. It was made up of 5 percent chubs, 37 percent lake trout, 37 percent shallowwater ciscoes, and 21 percent other fish comprising nine species.

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U. S. GOVERNMENT PRINTING OFFICE :1956 O - 37831